

Design, Safety, Schedule, and Cost Assessment of Parsons/Honeywell WHEAT Total Solution

Final Technical Report

**Prepared for:
Program Manager for Assembled
Chemical Weapons Assessment
(PMACWA)
APG, Maryland**

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2.0 Introduction

The Assembled Chemical Weapons Assessment (ACWA) Program originated from laws enacted by Congress in 1996. Public Law 104-201 established the requirement for an assessment of alternative technologies for demilitarization of assembled chemical munitions. Public Law 104-208 provided funding to identify and demonstrate not less than two alternatives to the Baseline incineration process for the demilitarization of assembled chemical munitions. Assembled chemical munitions for this purpose represent the chemical weapons stockpile configured with fuzes, explosives, propellant, chemical agents, shipping and firing tubes, and packaging materials.

2.1 General Background

The ACWA Program involved a three-phased approach – evaluation criteria development, technology assessment, and demonstration of the technologies.

Evaluation Criteria Development

The evaluation criteria development phase took place during the months of May, June and July 1997. During this phase, the Program Manager for Assembled Chemical Weapons Assessment (PMACWA), in concert with the Dialogue on ACWA, developed the program evaluation criteria. These evaluation criteria were grouped into four major categories: Process Efficacy/Process Performance; Safety; Human Health and Environment; and Potential for Implementation.

Technology Assessment

The technology assessment phase took place during the September 1997 – June 1998 timeframe. In July 1998, based on the evaluation of the Demonstration Work Plans and a determination of best value to the government, three Technology Providers were awarded task order contracts to conduct demonstration testing. They were Burns and Roe (Plasma Arc), General Atomics (Neutralization/Supercritical Water Oxidation), and Parsons/Honeywell (Neutralization/Biotreatment).

Demonstration I Testing

The actual demonstrations (Demonstration I) of alternative technologies took place between January and May 1999. The purpose of the demonstrations was to validate the chosen technologies' ability to safely destroy chemical munitions and their associated materials. The evaluation of the demonstrations took place between June and August 1999. The evaluations were performed collectively by the Technology Providers, Dialogue participants, PMACWA contractor personnel and PMACWA personnel. The PMACWA Program Evaluation Team (PET) and representatives from the Dialogue conducted the assessment of the technology demonstrations. Using the previously approved evaluation criteria, the PET and representatives from the Dialogue assessed each of the technologies demonstrated. The information used for these assessments included the Technology Providers' demonstration reports, the PMACWA's milestone reports, the validated demonstration data, and all previous documentation submitted by the Technology Providers. As reported in the September 1999 Supplemental Report to Congress, the technology assessment concluded that the General Atomics (General Atomics Total Solution

– GATS) and Parsons/Honeywell (Water Hydrolysis of Energetics and Agent Technology – WHEAT) technologies were viable to go to pilot testing.

2.2 Certification Decision Process

The PMACWA is currently completing Engineering Design Study (EDS) I testing for the General Atomics (GATS) and Parsons/Honeywell (WHEAT) technologies to develop the information necessary to satisfy the requirements in the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999 (Public Law 105-261).

The EDS I testing (to date) has supported the preparation of an Engineering Package that will be the basis for the cost, schedule and safety Certification Decision process. The Engineering Package includes drawings and documentation sufficient to generate capital and operational and maintenance costs to within ± 20 percent. The Engineering Package also includes a cost estimate that was reviewed/adjusted and used to develop a program life cycle cost estimate (LCCE). A program schedule is included in the package along with a Preliminary Hazards Analysis (PHA) that will be used as a tool in the safety certification process. Parsons/Honeywell developed an Engineering Package for the Pueblo Chemical Agent Disposal Facility (PUCDF) only, while General Atomics developed an Engineering Package for the PUCDF and is currently developing a package for the Blue Grass Chemical Agent Disposal Facility (BGCDF). This is due to the fact that the PUCDF would process only mustard munitions while BGCDF would process both mustard and nerve agent munitions; WHEAT was concluded to be viable for treating only mustard munitions while GATS was deemed viable for treating both mustard and nerve agent munitions. These packages will be used for the Certification Decision process, the request for proposals (RFPs) for the two demilitarization sites, and for Environmental Impact Statement (EIS) development and Resource Conservation and Recovery Act (RCRA) permit applications.

Preliminary Engineering Packages by Parsons/Honeywell (for WHEAT) and General Atomics (for GATS) were submitted to the Government on 27 October 2000. Design reviews were conducted by PMACWA and Arthur D. Little at the end of November 2000 and changes were made to these packages as a result. The Final Engineering Packages for both WHEAT and GATS were submitted to the Government on 5 January 2001.

As part of Public Law 105-261, and the certification process, the Under Secretary of Defense for Acquisition, Technology and Logistics (ATL) must certify in writing to Congress that any alternative proceeding to pilot testing is—

- (i) as safe and cost effective for disposing of assembled chemical munitions as is incineration of such munitions; and
- (ii) capable of completing the destruction of such munitions on or before the later of the date by which the destruction of the munitions would be completed if incineration were used or the deadline date for completing the destruction of the munitions under the Chemical Weapons Convention; . . .

This report provides Arthur D. Little's independent assessment of Parsons/Honeywell's Total Solution (WHEAT) Engineering Package, and compares the results to Baseline incineration (as represented by the PUCDF). This report constitutes the most comprehensive information available for the ACWA Program Manager to formulate his recommendation to the Under Secretary of Defense for ATL regarding "certification" of an agent and energetic hydrolysis (neutralization)/biotreatment technology (illustrated by WHEAT) required under Public Law 105-261.

3.0 Overall Objective of Independent Assessment

The overall objective of Arthur D. Little's independent assessment of the Parsons/Honeywell Water Hydrolysis of Energetics and Agent Technology (WHEAT) Engineering Package (dated January 2001) was to provide support for the Certification Decision of the Undersecretary of Defense for Acquisition, Technology and Logistics (ATL) as directed in Public Law (PL) 105-261. Public Law 105-261 requires that for an alternative technology (to incineration) for the destruction of lethal chemical munitions to be considered, the Under Secretary of Defense for ATL must certify in writing to Congress that it is:

- As safe and cost effective for disposing of assembled chemical munitions as is incineration of such munitions; and
- Capable of completing the destruction of such munitions on or before the later of the date by which the destruction of the munitions would be completed if incineration were used or the deadline date for completing the destruction of the munitions under the Chemical Weapons Convention.

In order to provide the Program Manager for Assembled Chemical Weapons Assessment (PMACWA) the most comprehensive information to formulate their recommendation to the Under Secretary of Defense for ATL regarding the Certification Decision, Arthur D. Little conducted the following assessment of the Parsons/Honeywell Water Hydrolysis of Energetics and Agent Technology (WHEAT) Engineering Package:

- Design Assessment
- Preliminary Hazards Analysis Review
- Schedule Assessment
- Cost Assessment

3.1 Design Assessment

The Design Assessment had four overall objectives with regard to review of the WHEAT design itself and the supporting Engineering Package:

1. Consistency with the requirements of the disposal facility design as set forth in the WHEAT Design Basis and the results of their Engineering Design Study (EDS) I testing;
2. Completeness in addressing all necessary aspects of the facility and, in particular, in terms of providing a "total solution;"
3. Core process viability in terms of operational efficacy and capability to consistently achieve both required levels of agent and energetics destruction as well as environmental performance; and
4. Adequacy to support the ± 20 percent cost estimate and to justify the proposed schedule (with modifications as required).

3.2 Preliminary Hazard Analysis (PHA) Review

Preliminary Hazards Analyses (PHAs) for the PMACWA EDS I alternative technologies (WHEAT and GATS) are performed to ensure the safety of the workers, the general public, and the environment during the disposal of assembled chemical weapons. The application of various hazard analyses reviews to the Department of Defense facilities are guided by MIL-STD-882D and other government codes and regulations applicable to this type of facility. The overall safety analysis goal is to assure the safety of the facility design, construction, equipment installation, systemization, operation, and closure/decommissioning.

The purpose of the PHA is to ensure that safety is addressed during the Engineering Design Study (preliminary engineering stage). The PHA applies the Failure Mode and Effects Analysis (FMEA) technique to identify and evaluate the potential hazards resulting from system component failures and to make recommendations for corrective design changes. The PHA focuses on hazardous materials, equipment, instrumentation, utilities, human actions (routine and nonroutine), and external factors that might impact the process during the preliminary design stages of the EDS I activities.

There are three specific objectives in conducting a PHA:

- Identify potential hazards, which reflect inherent risks of the unit operations involved;
- Analyze the design at an early stage and provide recommendations to guide the designers in mitigating potential hazards; and
- Identify residual hazards of significance that must be addressed in later design phases.

The PHA Review focussed on three objectives:

1. Review of the Parsons/Honeywell WHEAT PHA for completeness, consistency and accuracy;
2. Assessment of the risk of the WHEAT design; and
3. Comparison of the safety of the WHEAT design to Baseline Incineration.

3.3 Schedule Assessment

The Schedule Assessment focused on two objectives:

1. Independent assessment of the Parsons/Honeywell WHEAT schedule for completeness, consistency, accuracy and realism; and
2. Independent comparison of the Parsons/Honeywell WHEAT schedule to the Baseline Incineration schedule.

The following guidelines (for both WHEAT and Baseline) were established for fulfillment of these objectives:

- The schedule would encompass all aspects of the design phase, construction, systemization, pilot testing, operations, and closure;
- The Defense Acquisition Executive (DAE) Review would culminate in a “Technology Decision” for Pueblo in December 2001;
- The Record of Decision (ROD) for Pueblo would be signed in December 2001;
- The Resource Conservation and Recovery Act (RCRA) Part B submittal would be made in January 2002;
- The RCRA Part B approval would be granted in September 2003; and
- The schedule estimates would be achievable within a confidence level of 75%. This means that relative to historical schedules for projects of similar type and scope, the estimated overall (end of operations) completion date would be expected to be achieved 75% of the time.

3.4 Cost Assessment

There were two principal objectives in the Cost Assessment:

1. Prepare a total life cycle cost estimate (LCCE) for the Parsons/Honeywell WHEAT technology adequate for certification of the technology.

The following guidelines were established for fulfillment of this objective:

- The cost estimate would encompass all aspects of technology development and implementation beginning with the inception of demonstration testing through the completion of all munitions operations. Facility closure would be explicitly excluded.
 - Costs would be for the complete demilitarization facility.
 - The WHEAT technology would offer a “total solution” for onsite treatment of all chemical munitions, agent and dunnage.
 - The cost estimate would be to a “relative” accuracy of +20%/-20% at a 90% confidence level. This means the WHEAT estimate is accurate within +20%/-20% to the same extent that Baseline is also accurate to within +20%/-20%.
 - The cost estimate would be to an “absolute” accuracy of +20%/-20% within a confidence level of 75%. This means that relative to historical costs for projects of similar type and scope, the estimate would be expected to be within 20% of final costs incurred 75% of the time.
 - Conform the WHEAT technology cost estimate bases, assumptions, cost factors and costing methodology as closely as possible with those used in the Baseline LCCE in order to provide the greatest degree of direct comparability and to ensure that the WHEAT LCCE would be within the same degree of accuracy as that for the Baseline.
2. Characterize and quantify, to the extent possible, the risk for cost growth.

The intent in meeting this objective has been to identify and characterize the principal technical and economic issues relevant to the implementation of the WHEAT technology that would pose significant potential for cost growth beyond the 20% limit established. This specifically excludes issues deriving from:

- Redirection (management and/or technical) of the overall Chemical Stockpile Disposal Project (CSDP);
- Changes in scope, Design Basis, or performance requirements relative to those established for the technology testing and design; and
- Availability of new information regarding the costs for Baseline equipment and facilities not made available to Arthur D. Little during the development and evaluation of the design and costs.

4.0 WHEAT Technology and Testing Description

The Parsons/Honeywell Total Solution, or Water Hydrolysis of Energetics and Agent Technology (WHEAT), for assembled chemical weapons demilitarization is presented in Table 4-1 and illustrated in Figure 4-1. Table 4-1 also shows the corresponding Baseline processes. The unit operations presented in this section are based on the Engineering Package that Parsons/Honeywell prepared and submitted to the Program Manager for Assembled Chemical Weapons Assessment (PMACWA) in January 2001. At the time that this package was submitted, the Engineering Design Studies I (EDS) testing had not been completed. The EDS I testing is currently expected to be completed in September 2001. The largest area of uncertainty (of which the current EDS I testing will hopefully resolve) surrounds the systems to access the agent cavity and drain/washout the agent.

The January 2001 Engineering Package is based on the use of a modified Multipurpose Demilitarization Machine (MDM) followed by a Rotary Washout Machine (RWM). The MDM is modified to contain the mustard “champagne” effect (experienced at Johnston Atoll Chemical Agent Disposal System [JACADS]) and invert the munition after the burster well is pulled to drain the agent. The Rotary Washout Machine (RWM) uses high pressure water to washout the agent heel. During the design of the Projectile Washout System (PWS) testing for the EDS I Test Program, Parsons/Honeywell has modified their approach to eliminate the burster well pull station for the 4.2-inch mortars and replace it with a system to cut off the mortar base plate and incorporate the RWM as a station in the modified MDM.

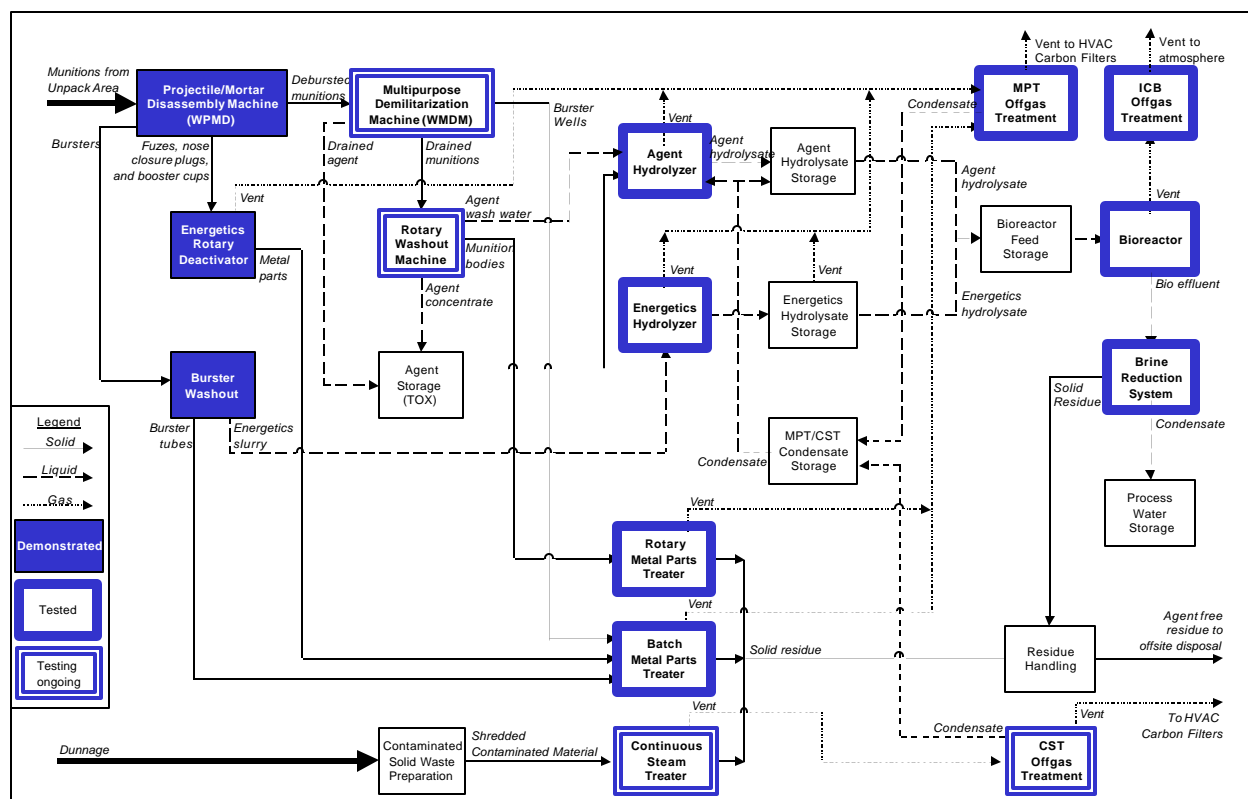
The Design, Preliminary Hazards Analysis, Schedule and Cost Assessments for WHEAT are based on the design proposed by Parsons/Honeywell in their January 2001 Engineering Package. At the conclusion of the EDS I Test Program, it will be necessary to review the results of the assessments provided in this report to ensure that they are still accurate given the outcome of the ongoing EDS I testing.

Table 4-1: Parsons/Honeywell Proposed Total Solution

Material to be Processed	Baseline	Parsons/Honeywell EDS I Engineering Package
Explosives	<ul style="list-style-type: none"> • PMD • Burster Shear • DFS 	<ul style="list-style-type: none"> • PMD • Burster Washout • Hydrolysis, Biotreatment
Agent	<ul style="list-style-type: none"> • MDM • LIC 	<ul style="list-style-type: none"> • Modified MDM, RWM • Hydrolysis, Biotreatment
Metal Parts	<ul style="list-style-type: none"> • MPF 	<ul style="list-style-type: none"> • Batch MPT, Rotary MPT
Fuzes	<ul style="list-style-type: none"> • PMD • DFS 	<ul style="list-style-type: none"> • PMD, Energetics Rotary Deactivator • Batch MPT
Solid Process Wastes	<ul style="list-style-type: none"> • DUN 	<ul style="list-style-type: none"> • Shredder, CST
Liquid Process Wastes	<ul style="list-style-type: none"> • LIC 	<ul style="list-style-type: none"> • Hydrolysis (if needed) • Biotreatment
Brine	<ul style="list-style-type: none"> • BRA 	<ul style="list-style-type: none"> • Evaporator/crystallizer

Source: Arthur D. Little, Inc.

Figure 4-1: WHEAT Block Flow Diagram



Source: Arthur D. Little, Inc.

4.1 WHEAT Technology Description

The WHEAT Technology is designed to demilitarize all the munitions in the Pueblo Chemical Agent Disposal Facility (PUCDF) stockpile (see Tables 4-2 and 4-3). This includes the ability to reconfigure the boxed munitions and destroy the propellants associated with them. The Parsons/Honeywell design is based on reconfiguring the munitions within the Munitions Demilitarization Building (MDB), processing the munitions immediately, and storing the propellants until all munitions have been processed and then destroying the propellants in a separate campaign. The WHEAT design is intended to process all the dunnage materials associated with the boxes as they are generated. The decision to have the Depot reconfigure the munitions and process the resultant dunnage was made by PMACWA after the Parsons/Honeywell Engineering Package was received; therefore, the Design Assessment did not consider the ability of WHEAT to handle reconfigured munitions only.

The munitions are transported from the Depot following standard PMCD procedures to the Munitions Storage Building (MSB). The munitions are held in the MSB for 24-hours to provide a buffer for the process and to allow the mustard in the munitions to thaw. The munitions are transported by truck from the MSB to the MDB. The munitions are unloaded in the vestibule area of the MDB for inventory check and inspection prior to moving them into the Unpack Area (UPA). The UPA is sized to provide a minimum of 4 hours of munitions storage. In the UPA, there are two munitions loading stations where the palletized munitions are unpacked manually.

Table 4-2: Parsons/Honeywell Design Basis – PUCDF Stockpiled Munitions

Item	Munitions Designation			
	M110HD/ M104HD	M60HD	M2/2A1 HD	M2 HT
Munitions				
Caliber	155 mm	105 mm	4.2 in	4.2 in
Number boxed	0	28,376	76,722	20,384
Number palletized	299,554	355,043	0	0
Total Number in stockpile	299,554	383,418	76,722	20,384
Munition Feed Materials				
Empty munition, lb/rnd	78.06	26.57	15.331	
Agent, lb/rnd	11.7	3	6	
Burster well, lb/rnd	2.03	1.48	0.77	
Burster tube, lb/rnd	0.42	0.255	0.474	
Burster energetic material	Tetrytol	Tetrytol	Tetryl	
Burster, lb/rnd	0.41	0.26	0.14	
Fuze well cup (Al.), lb/rnd	0.06	0.06	---	
Nose closure	Lifting plug	Fuze	Fuze	
Nose closure, lb/rnd	1.75	1.405	0.782	
Detonator, lb/rnd	---	0.001	0.001	
Total munition, lb/rnd	94.6	38.8	25	
Propellant, lb/rnd (boxed munitions)	---	2.75	0.62	

Note: There are slight discrepancies between the Parsons/Honeywell munitions design basis and the PMCD design basis for PUCDF.

Source: Parsons/Honeywell January 2001 Engineering Package

The dunnage is sent to the Continuous Steam Treater (CST) for treatment and the munitions are loaded on conveyors for processing.

After unpacking, the projectiles and mortars are conveyed to the Energetics Containment Room (ECR) where the fuzes and bursters are removed in a Baseline Projectile/Mortar Demilitarization (PMD) machine. The fuzes are conveyed to the Energetics Rotary Deactivation (ERD) unit where they are thermally deactivated and the residual metals are then sent to the Batch Metal Parts Treater (BMPT) for 5X treatment. Energetics are washed out of the burster tubes using high pressure water in the Burster Washout Machine (BWM). The energetics slurry is then sent to the Energetics Hydrolysate Area, and the munition bodies are conveyed to a modified MDM. There is no buffer storage between the PMDs and the MDMs.

The modified MDM pulls the burster well and inverts the munition body to drain as much agent from the munition as possible. The drained agent is pumped to the Toxic Storage Area (TOX) to await hydrolysis. The drained munition is moved to the RWM where moderate pressure water at ambient temperature is used to wash the agent heel from the munition. The washout water is allowed to settle and the heavier agent concentrate sinks to the bottom of a sump and is pumped to the TOX to await hydrolysis. The cleaned munition bodies are transferred to the Rotary Metal Parts Treater (RMPT) for 5X decontamination.

Table 4-3: Parsons/Honeywell Design Basis – Secondary Process Wastes

Waste Description	Design Assessment Basis ⁴	Parsons/Honeywell Basis ⁵
Dunnage ¹ -- Mixture of glass, plastic, wood, metal bands, paper and packaging material not related to munitions packaging	1lb/rnd 780,000 lb total off-site disposal	Quantities not addressed Disposal not addressed
Decon solution -- NaOH, NaOCl	5.32 lb/rnd 4,150,000 lb total treated in agent hydrolyzer	5.32 lb/rnd 3,800,000 lb total treated in agent hydrolyzer
DPE suits -- Chlorinated PVC, PVC, latex, butyl rubber	0.15 lb/rnd 117,000 lb total treated in CST	0.11 lb/rnd 80,892 lb total treated in CST
Wooden pallets from munitions ² -- Some contamination by agents and energetics	3.56 lb/rnd 2,770,000 lb total treated in CST	2.8 lb/rnd 2,000,000 lb total treated in CST
Spent carbon -- Generated by WHEAT process	0.3 lb/rnd 234,000 lb total treated in CST	0.18 lb/rnd 139,000 lb total treated in CST
Waste oils ³	0.3 lb/rnd 234,000 lb/rnd treated in CST	Quantities not addressed treated in CST
Trash, debris, protective clothing ¹	0.2 lb/rnd 156,000 lb total off-site disposal	Quantities not addressed Disposal not addressed
Miscellaneous metal parts -- Non-munition scrap metal	0.4 lb/rnd 312,000 lb total treated in Batch MPT	Quantities not addressed Disposal not addressed
Spent hydraulic fluid ³	0.2 lb/rnd 156,000 lb total treated in CST	Quantities not addressed treated in CST

1. These wastes are assumed not to be contaminated with agent.
2. All pallets whether they are contaminated or not are treated on-site.
3. All process waste oils and spent hydraulic fluids are assumed to be glycol-based and that no petroleum-based oils will be used.
4. The Design Assessment has considered all the secondary waste generated in the facility. This includes the pilot testing period as well as the operating campaigns.
5. Parsons/Honeywell design basis does not consider the secondary process waste generated during the pilot testing. Their total pounds of waste is based on processing 714,161 munitions during the operating campaigns.

Source: Arthur D. Little, Inc. and Parsons/Honeywell January 2001 Engineering Package

Agent and energetics hydrolysis is conducted in batch continuously stirred tank reactors with appropriate heating and cooling systems. The hydrolysis is performed using standard Army procedures: caustic for energetics and hot water for mustard agents. The resulting hydrolysates are sent to the Immobilized Cell Bioreactors (ICBTM) for biodegradation of the hydrolysis products and the removal of the Schedule 2 compound thiodiglycol. The effluent from the ICBsTM is sent to the Brine Reduction System (BRS), which is comprised of a brine concentrator, an evaporator/crystallizer, and dewatering equipment. The recovered water from the BRS is pumped to the Process Water Tank for reuse and the dewatered solids are shipped

offsite for disposal. If the ICB™ effluent is high in suspended solids, it will go to a clarifier first, with the supernatant then going to the BRS and the sludge going to dewatering and off-site disposal.

All metal parts are treated in either the RMPT or the BMPT. The RMPT handles all projectile and mortar bodies after they have been washed out in the RWM. The RMPT is a cylindrical structure rotating at a prescribed speed inside of a cylindrical furnace. The cylindrical structure contains 15 cages that run the length of the furnace. One munition at a time is loaded into a cage and as the munition is loaded one munition is pushed out the other end. The cylindrical structure then rotates to the next cage and another munition is loaded into the RMPT. Each of the 15 cages holds ten 105mm projectiles, ten 4.2-inch mortars, or seven 155mm projectiles. As the munitions are discharged, they are placed in an air lock and monitored for agent prior to being released to the Residual Handling Area (RHA).

The BMPT handles all metal from the Energetics Rotary Deactivator, Burster Washout Machine, and burster wells from the modified MDM. The metal parts to be decontaminated in the BMPT are placed into reusable metal boxes and conveyed to the BMPT. Three of the metal boxes will be loaded into the BMPT during each cycle. At the conclusion of the decontamination cycle the BMPT is cooled down and monitored for agent prior to releasing the metal parts to the RHA.

Both of the MPTs use induction coils and superheated steam to raise the temperature of the metal parts to a minimum of 1000 °F for 15 minutes. This allows the metal parts to be certified agent and energetic free, or 5X. The exhausts from the MPTs are condensed to remove the steam (as water) and organics. The noncondensable gases are further treated in a patented Catalytic Oxidizer (CatOx) before being passed through carbon beds and released to the environment. The condensates are analyzed to ensure that they are agent free. If the condensates are found to have agent, they are sent to the Agent Hydrolysis Area for treatment with the spent decon solutions. If the condensates are agent free, they are combined with the agent and energetic hydrolysates and treated in the ICBs™.

Dunnage, demilitarization protective ensemble (DPE) suits, spent carbon, and other solid process wastes are first size-reduced and then decontaminated in the CST. The CST is similar to the MPT except that it uses an auger to move the shredded solids through the inductively heated reactor in a steam environment. The temperature of the solids is raised to a minimum of 1000 °F for 15 minutes. This allows the ash and residual solids to be certified as agent and energetic free (5X). The exhaust from the CST is condensed in a caustic scrubber to remove steam (as water) and chlorine released from the DPE. The noncondensable gases are catalytically oxidized to carbon dioxide and water before being passed through carbon beds and then released to the environment. The condensate is analyzed to ensure that it is agent free. If the condensate contains agent it is sent to the Agent Hydrolysis Area for treatment with the spent decon solutions. If the condensate is agent free it is combined with the agent and energetics hydrolysates and treated in the ICBs™.

4.2 WHEAT Testing During PMACWA Program

The Parsons/Honeywell Team was selected for PMACWA Demonstration I testing in 1998 along with General Atomics and Burns and Roe. During Demonstration I, Parsons/Honeywell tested three unit operations:

- Rocket Cutting and Washout to access M55 rockets and water jet washout to size reduce and slurry Comp B bursters and M28 propellant.
- Metal Parts Treater to 5X secondary process wastes (wood, DPE, carbon, and fiberglass firing tubes) and mortars with 10% agent heels. The Demonstration I Program also included direct injection of agent to the CatOx unit to test its ability to destroy agents.
- Biological Treatment of agent and energetic hydrolysates.

The test objectives for the Parsons/Honeywell demonstrated unit operations are presented in Table 4-4, and the Test Program for each of the three unit operations is discussed in Section 4.2.1, Parsons/Honeywell Demonstration I Test Program. Additional information is provided in the PMACWA Supplemental Report to Congress dated September 1999 and the Arthur D. Little Final Technical Report entitled “*Summary of Parsons/Honeywell Demonstration I – RC&W, MPT, and ICBs*” dated March 2001.

At the conclusion of the Demonstration I Test Program, PMACWA selected Parsons/Honeywell to continue the development of the WHEAT process during the EDS I Test Program. During the EDS I Test Program, Parsons/Honeywell conducted four unit operations based upon the additional data required to prepare the Engineering Package for PUCDF:

- Biological treatment of HD and tetrytol hydrolysate
- CatOx treatment of HD in the gas stream
- CST to 5X secondary process wastes (wood, DPE, carbon, and fiberglass firing tubes)
- Projectile Washout System (PWS) to access the mortar agent cavity, drain the agent, and wash out the agent heels

The test objectives for the Parsons/Honeywell unit operation tested during the EDS I Test Program are presented in Table 4-5, and the Test Program for each of the four unit operations is discussed in Section 4.2.2, Parsons/Honeywell EDS I Test Program.

4.2.1 Parsons/Honeywell Demonstration I Test Program

Rocket Cutting and Washout. The RC&W process was demonstrated at Dugway Proving Ground (DPG), Utah in 1999. The tested system was designed to provide an alternative to the reverse assembly process for M55 rockets by separating the agent and energetic components from these munitions to allow for subsequent treatment of the separate components. The tested process used a high-pressure water jet with abrasives to perform circumferential cuts of a rocket along its length to safely access rocket parts for removal and treatment. Once exposed, fuzes and accessory components were removed robotically and warhead energetics were removed through

Table 4-4: Parsons/Honeywell Demonstration I Test Objectives

Test Objectives	Outcome of Testing
Rocket Cutter and Washout (RC&W) System <ul style="list-style-type: none"> • Demonstrate the ability to perform circumferential cuts of a rocket at required locations along the rocket length • Demonstrate effective fluid mining and separate collection of rocket bursters, motor propellants, and residual agent simulant • Demonstrate the ability to maintain control of rocket metal and plastic parts from cutting and fluid mining operations • Determine the energetic particle size of mined rocket bursters and propellant • Determine the requirements for separating used grit from the residual cutting solution 	<ul style="list-style-type: none"> • Met. The RC&W was able to cut the rocket between the fuze and burster and between the warhead and motor. • Met with Reservation. The RC&W was able to washout the Comp B burster however the RC&W was not able to washout the M28. • Met. The system maintained control over all cut parts and slurried materials. • Met. The average particle size for the washed out Comp B was 500 um. • Met. The system was able to separate the grit from the water.
Metal Parts Treater (MPT) <ul style="list-style-type: none"> • Validate the ability of the MPT process to treat process wastes/dunnage • Validate the ability of the MPT process to achieve a 5X condition for metal parts contaminated with HD • Identify pyrolysis products generated in the MPT during the processing of process wastes/dunnage and their impact on the downstream condenser • Characterize the liquid effluent from the MPT condenser to determine its suitability for treatment by hydrolysis • Validate the ability of the MPT condenser and the CatOx to eliminate chemical agents and Schedule 2 Compounds from process gas streams • Determine the potential for fouling and plugging of the CatOx as a result of MPT operation • Characterize gas, liquid, and solid process streams from the MPT and CatOx unit operations 	<ul style="list-style-type: none"> • Met. The MPT met 5X conditions for wood, DPE, carbon, and fiberglass and all emissions from the MPT were handled by the downstream systems. • Met. The MPT met 5X conditions for the HD heel in the 4.2-inch mortar. • Met. The condensate and the noncondensable gases were characterized and the downstream condenser was not fouled. • Met. The condensate from each dunnage run was characterized but only 1 of the 3 HD heel runs was characterized due to the presence of HD above 200 ug/L. The dunnage condensate had significant concentrations of VOCs and SVOCs that might cause a problem in hydrolysis. The HD heel had lower concentrations of VOCs and SVOCs as well as thiodiglycol, dithiane, and thioxane. These concentrations are not expected to cause a problem. • Met with Reservation. Two out of three of the post CatOx gas samples contained significant quantities of HD. • Met. Given the performance of the CatOx during the HD Heel runs there is a concern that the catalyst may have fouled. • Met. The gas, liquid, and solid process streams were characterized except when agent was present at a level above the clearance requirements.

Table 4-4: Parsons/Honeywell Demonstration I Test Objectives (continued)

Test Objectives	Outcome of Testing
ICB™ System <ul style="list-style-type: none"> • Validate the ability of the HD ICB™ process to eliminate Schedule 2 Compounds (thiodiglycol) present in the HD hydrolysate feed • Confirm the presence/absence of agent in the effluents of the ICB™ system • Validate the ability of the Agent Hydrolysate and HD ICB™ systems to achieve a Destruction and Removal Efficiency (DRE) of 99.9999% for HD • Validate the ability of the Energetic Hydrolysate and HD ICB™ systems to achieve a DRE of 99.999% for TNT and tetryl • Develop mass loading and kinetic data to allow for scale up of ICB™ system unit operations • Validate the ability of the CatOx to eliminate specified volatile organic compounds (VOCs), semi-VOCs, and Schedule 2 Compounds from the ICB™ process gas stream • Determine the potential impact of operating conditions on the fouling and plugging of the CatOx • Characterize gas, liquid, and solid process streams from the ICB™ process (including CatOx) 	<ul style="list-style-type: none"> • Met. The HD ICB™ was able to reduce the thiodiglycol to below detection limits consistently. • Met. HD was not found in any of the HD ICB™ samples • Met. The Agent Hydrolysis system (operated by PMACWA at ECBC) was able to achieve a DRE of greater than 99.9999% for HD. • Met. The Energetic Hydrolysis system (operated by PMACWA at Pantex) was able to achieve a DRE of greater than 99.999% for TNT and Tetryl. • Met with reservation. Mass loading and kinetic data was developed from the test program for each of the unit operations but it was for a relatively short period, relatively little biomass was generated during the testing, the pH of the ICB™ was hard to control, and the salts in the water recycle stream appeared to cause operating problems • Met. The off gas from the ICB™ had relatively low concentration of organics and the CatOx reduced these levels further. Dithiane and thioxane were found both before and after the CatOx at low levels. • Met. The CatOx operated without problem during the test program. • Met. The gas, liquid, and solid process streams were characterized.

Source: Arthur D. Little, Inc.

Table 4-5: Parsons/Honeywell EDS I Test Objectives

Test Objectives	Outcome of Testing
ICB™ System <ul style="list-style-type: none"> • Demonstrate long-term (4 months [4 biomass retention times]), continuous operation of the HD ICB™ exclusive of upset condition, using the proposed full-scale operating conditions (e.g., aeration, effluent recycling) • Demonstrate the ability of the secondary unit operations (e.g., clarifier, filter press, and crystallizer) to operate as proposed • Confirm critical design parameters (e.g., aeration rate, CatOx loading) developed during PMACWA Demo I Test Program • Demonstrate effective control of the biomass throughout the HD ICB™ process including growth within the ICB™ unit, separation within the clarifier, and filtration • Demonstrate the effectiveness of the proposed full-scale control strategy for the ICB™, clarifier, CatOx, crystallizer, and filter press • Characterize the CatOx outlet, crystallizer offgas, biomass and brine salts from the ICB™ process • Demonstrate/optimize effective stabilization of solids, if required • Demonstrate the ability of the HD ICB™ unit to treat the neutralized CST condensate as part of the Feed stream to the ICB™ 	<ul style="list-style-type: none"> • Met. The HD ICB™ operated at steady state for approximately 100 days at a rate of 40 gal HD hydrolysate/day/1000 gal reactor volume and for 30 days at a rate of 50 gal HD hydrolysate/day/1000 gal reactor volume. • Met. The HD ICB™ produced very few biosolids during the test therefore the clarifier and filter press were not used and the ICB™ effluent flowed directly to the evaporator. The evaporator operated to recover water during the test but never produced dry salts. Test were performed at the suppliers facilities on 5 gallons of brine to confirm design. • Met. The system was operated at the design conditions for 130 days without major incident. • Met. The HD ICB™ produced very few biosolids during the test therefore the clarifier and filter press were not used and the ICB™ effluent flowed directly to the evaporator. The ICB™ did not show any signs of plugging during the testing. • Met. The control strategy for the ICB™ and the CatOx worked effectively during the test. • Met. The CatOx outlet gas was characterized; however, the biomass and the crystallizer offgas were not due to the operation of the system. Brine salts were characterized from the suppliers test. • Met. Solids stabilization was not required. • Met. Wood condensate and wood/DPE condensate were tested in the HD ICB™ at a rate up to 3 gal condensate/day/1000 gal reactor volume without problem.
HD CatOx <ul style="list-style-type: none"> • Observe long-term (500 hrs) operation of the CatOx Unit with HD • Observe whether the catalyst loses efficiency (due to poisoning, fouling and/or plugging) • Estimate the expected catalyst life under continuous HD operations • Verify the absence of selected contaminants after the downstream carbon bed 	<ul style="list-style-type: none"> • Met. The CatOx unit was operated for approximately 640 hours at an HD feed rate of 10mg/m³ without HD being detected after the CatOx. • Met. The catalyst efficiency did not appear to drop during the test. The HD concentrations after the CatOx were always nondetect and pressure drop across the CatOx only rose slightly. • Met. The catalyst life is estimated to be greater than 30 months. • Met. The contaminants in the gas stream after the carbon bed were very low.

Table 4-5: Parsons/Honeywell EDS I Test Objectives (continued)

Test Objectives	Outcome of Testing
Continuous Steam Treater (CST) – Testing is currently on-going	
<ul style="list-style-type: none"> • Generate required design/operating data for development of a full-scale design, a preliminary hazard analysis, and a life cycle cost and schedule • Characterize neutralized CST condensate for selected chemical constituents and physical parameters and the presence or absence of hazardous or toxic compounds • Observe the long-term operability, reliability and ease of material handling of the CST while continuously being fed wood from pallets, DPE suit material, and carbon from filter trays • Observe the effectiveness of the proposed full-scale control strategy for the CST • Verify critical design parameters for the CST on dunnage (e.g., temperature, steam flow rate, CatOx loading, feed throughput rate) originally developed during the PMACWA Demonstration I Test Program • Observe the ability of the CatOx unit to effectively treat uncondensed gases over a long-term operation. Determine whether the catalyst loses efficiency due to poisoning, fouling, and/or plugging. Project expected CatOx catalyst life under continuous CST operation • Observe system equipment after each run and after completion of testing program and develop a matrix of indicators for preventive maintenance 	<ul style="list-style-type: none"> • On Going. The CST has operated for approximately 500 hours over a 4 month period. During that time design/operating data has been collected. • On Going. The CST condensate has been analyzed and found to contain significant quantities of hazardous compounds including dioxins and furans. The operating parameters are being modified in an attempt to reduce the generation of these compounds. • On Going. Operability and reliability problems have been observed in several critical areas both upstream and downstream of the CST. The largest problem has been the generation of a large quantity of fine particulate which has fouled downstream equipment. • On Going. Due to the operability problems it is not clear whether the control strategy is effective. The final two test runs, after system modifications, are expected to verify the control strategy. • On Going. The optimal design parameters have not been set due to the problems encountered during testing. The final two test runs, after system modifications, are expected to verify the critical parameters. • On Going. The CatOx units had significant fouling problems that appear to be due to fine particulate from the CST. The system modifications are expected to reduce particulate loading in the downstream equipment and therefore protect the CatOx units. The CatOx units will be replaced during system modifications • On Going. No data has been provided on this objective yet. However, the testing has shown a unit that is no more than 50% available now and not expected to be greater than 80% available in its final configuration.
Projectile Washout System (PWS) – Testing has not started; the expected start date is 7 July 2001	
<ul style="list-style-type: none"> • Determine the operating characteristics of the PWS to allow the full-scale system to be designed • Validate the basis for the average operating rate for the full-scale system • Determine the reliability/availability/maintainability (RAM) characteristics of the PWS to be incorporated into the full-scale design • Determine the quantity of agent going to the Metal Parts Treater • Evaluate the PWS system materials of construction for application to the full-scale design • Characterize the HD hydrolysate to ensure compatibility with the ICB™ system • Complete a system water balance around the PWS and Agent Hydrolyzer to ensure that the hydrolyzers are properly sized and 4% HD hydrolysate can be produced 	No Testing has been conducted to date.

Source: Arthur D. Little, Inc.

a process of fluid mining with a high-pressure water boring jet. It was shown in the test that M28 propellant could not be removed in this way. Consequently, the propellant was pulled from the motor casing and an attempt was made to shred the propellant using existing equipment.

The demonstrated RC&W system consisted of five major pieces of equipment including a water jet skid; a robotic arm used for cutting, boring, and component removal functions; a rotating fixture to hold and rotate the rocket; a low-speed shredder; and a collection and sampling skid.

To meet the objectives established for the demonstration of the RC&W, a series of test runs was established as summarized in Table 4-6.

A sampling and analysis program for the RC&W was conducted to analyze the energetic washout stream for energetic particle size and total suspended solids content of input and output water streams. Process monitoring of the system during operation included a visual/recorded observation of the cut and washed out parts, water consumption, and grit (abrasive) consumption.

Parsons/Honeywell demonstrated that the components of the RC&W could be operated in accordance with the overall established specifications and achieve planned operational performance. Despite the successes, the RC&W system was not able to meet all the test objectives established for its demonstration. The system was able to successfully remove fuzes, wash out the Comp B burster, and remove the warheads; however, it was unable to wash out the M28 propellant. The primary observations and results include:

- Twenty-one fuzes were cut off the M60 and M61 rockets without incident.
- Nine simulated Comp B bursters and 12 actual Comp B bursters were washed out with an average particle size of 500 um.
- The warhead was cut from nine simulated M60 rockets and 12 M61 rockets containing live energetics.
- During the removal of the warhead on the M61 rockets, the water jet cut through the igniter assembly releasing the black powder.
- After minor adjustments to the retraction of the robot arm, the system was able to pull the spring, wires, and rods from the rocket motor of the M61 rockets.
- Two attempts to wash out the M28 propellant failed. In both cases, the washout nozzle cut a spiral in the rocket motor, but the rubbery and fibrous consistency of the propellant did not allow adjacent material to break away.

MPT System. The MPT was demonstrated at the Chemical Agent Munitions Disposal System (CAMDS) at Deseret Chemical Depot, Utah in 1999. The MPT provides an alternative process for decontaminating metal parts and miscellaneous dunnage resulting from munitions access and disassembly processes so they meet the Army's decontamination criteria. Through the use of induction heating and superheated steam, metal parts and dunnage items were decontaminated in the demonstration to a 5X level. This treatment, combined with treatment of MPT off-gases in a catalytic oxidation unit (CatOx), also resulted in the transformation of chemical agents to less harmful products.

Table 4-6: Demonstration I Test Runs for the RC&W

Test Type	Feed Characteristics	Purpose of Test	Number of Runs
Workup	M60 Rockets with burster and propellant packages replaced with simulant	Determine optimum cutting and boring rates and overall effectiveness with inert rockets	4
Validation	M60 Rockets with burster and propellant packages replaced with simulant	Validate the use of water jets to disassemble rockets and bore out the burster charge and propellant	5
Workup	M60 Rockets (configured with bursters and propellants)	Demonstrate the ability of the system to safely cut live rockets	2
Validation	M61 Rockets (configured with bursters and propellants)	Validate the use of water jets to disassemble rockets and boring the burster charge and propellant	10
Validation	M61 Rocket Motor segments from the cutting validation tests	Demonstrate the ability of the system to remove the M28 propellant from the motor casing	10
Validation	M28 Propellant from M61 Rocket Motors from the cutting validation tests	Demonstrate the ability of the system to shred M28 propellant	10

Source: Arthur D. Little, Inc.

The primary components of the demonstrated MPT system included a steam generator, steam superheater, and induction heaters to provide for the heating of the test items to the required temperatures and holding times and the generation of a hot gas stream to decontaminate and transform chemical agents. Condensers cooled the resulting gas stream to remove and collect residual agent or organic compounds. The gas stream exiting the condenser was further treated in a CatOx unit to destroy any residual contaminants not removed as condensate. After treatment in the CatOx unit, the acidic gas stream was neutralized in a lime bed before passing to the test facility exhaust system.

To meet the objectives listed in Table 4-4, a series of test runs was established as described in Table 4-7.

The scope of the sampling, analysis, and monitoring program for the MPT included real-time monitoring for chemical agent compounds, process monitoring, and acquisition of validation data.

Parsons/Honeywell performed sampling, analysis, and monitoring necessary for obtaining process information. These process-related data included flow, pressure, and temperature measurements using indicators positioned in process streams throughout the MPT system. Continuous emission monitors (CEMs) for CO, CO₂, O₂, and total hydrocarbons (THC) were also used for process monitoring.

For the purposes of validation, the MPT demonstration testing included the following types of emission and waste stream characterizations:

- Real-time monitoring of CO, CO₂, O₂, THC, flow, and temperature;

- Sample collection and off-site analysis for volatile organics, semi-volatile organics, anions, metals and particulate, dioxins/furans, hydrogen halides, hydrogen cyanide, ammonia, and hazardous waste characteristics; and
- Sample collection and on-site analysis for chemical agents, methane, NO_x, SO₂, and H₂S.

Table 4-7: Demonstration I Test Runs for the MPT System

Test Type	Feed Type	General Feed Characteristics	Number of Runs
Workup	None	Empty test chamber	1
Process Waste/Dunnage	Carbon	Clean granular activated carbon (~0.5 lb.)	3
	Fiberglass Firing Tubes	Uncontaminated, 1-2 lb. segments	3
	Wood Pallets	0.5 - 0.75-lb. segments spiked with PCP	3
	Bagged Demilitarization Protective Ensemble (DPE) with boots and gloves	Uncontaminated sets	3
Agent Workup	M2A1 Mortar	Spiked with diesel fuel (Run 1) and nonane and heptane (Runs 2 and 3)	3
GB Agent	M2A1 Mortar	Mortar spiked with ~250 ml GB	3
GB Agent	Neat GB	Injection of neat GB over several hours	1
VX Agent	M2A1 Mortar	Mortar spiked with ~250 ml VX	3
VX Agent	Neat VX	Injection of neat VX over several hours	1
HD Agent	M2A1 Mortar	Mortar spiked with ~250 ml HD	3
HD Agent	Neat HD	Injection of neat HD over several hours	1

Source: Arthur D. Little, Inc.

In general, the MPT proved to be capable of meeting all of the demonstration objectives for all of the feed types as shown in Table 4-4. Of particular note is the ability of the process to reliably achieve a 5X condition for metal parts and dunnage (i.e., achieving a temperature of 1000°F for a period of more than 15 minutes) while reducing the organic loading in the offgas. While the MPT system did reduce the organic loading, the quantity of organics going to the CatOx was higher than Parsons/Honeywell had initially anticipated. In addition, there was some difficulty controlling the rate at which the organics were sent to the CatOx. Because of these issues and the fact that the MPT test unit as designed was a proof of concept, Parsons/Honeywell tested the CST during the EDS I Program (see Section 4.2.2, Parsons/Honeywell EDS I Test Program).

The demonstration tests met one objective with reservation because it was not clear whether the CatOx unit had not lost efficiency over the test program. Significantly higher levels of chlorinated compounds were observed at the outlet of the CatOx during the HD mortar runs (the last validation test run) than in the earlier tests. This result may indicate fouling of the catalyst or may be a function of the difficulty in destroying HD. In addition, the MPT met the agent DRE objective with reservation because the CatOx did not meet a 6 9's DRE for the HD injection run. As discussed above, the cause of this failure could either be associated with a loss of efficiency in the CatOx or the difficulty in destroying HD. The CatOx did achieve the required DRE for all

other agent injection runs. The problem associated with the CatOx was the focus of the EDS I CatOx test (see Section 4.2.2, Parsons/Honeywell EDS I Test Program).

HD ICB™. The HD ICB™ was demonstrated at Aberdeen Proving Ground (APG), Maryland to treat HD and energetic hydrolysates. The ICB™ system in combination with the hydrolysis provide an alternative process to Baseline incineration for liquid agent and energetic wastes and rely on the ability of biological activity to reduce the toxicity and destroy intermediate components of neutralized chemical agents and energetics.

The HD ICB™ treatment subsystem consisted of a 200-gallon feed tank and a horizontal tank system containing three ICB™ cells with volumes of 500 gallons, 250 gallons, and 250 gallons. The effluent from the final ICB™ cell flowed to a 50-gallon flocculation reactor vessel with a drum mixer. Ferrous sulfate and hydrogen peroxide were added to the flocculation reactor to enhance settling of the biomass.

In this system, a nutrient delivery system was used to deliver a mixture of nutrients into the first ICB™ cells. Sodium hydroxide was added as necessary to control the pH within the reactor cells. Chemical feed systems were also included for the addition of hydrogen peroxide and ferrous sulfate to the flocculation reactor and for the addition of polymer prior to the clarifier to enhance flocculation and precipitation of solids.

Overflow from the flocculation reactor flowed to an inclined plate clarifier where precipitated solids were separated from the treated water. The clarified water was pumped into a storage tank for subsequent treatment by reverse osmosis (RO). The retentate from the RO unit was disposed of off-site and the recovered water was recycled to the ICB™ feed tank.

Exhaust gases from the bioreactors were electrically heated and passed through a CatOx reactor to ensure the destruction of organic compounds. Acid gases produced in the CatOx were passed through a lime bed to remove the acids prior to release of the gases to the test facility ventilation system.

The scope of the sampling, analysis, and monitoring program for the ICB™ systems included real-time monitoring for chemical agent compounds, process monitoring, and the acquisition of validation data. Parsons/Honeywell performed sampling, analysis, and monitoring necessary for obtaining process information. Related data included flow rates, pressures, temperatures, pH, and liquid levels using indicators positioned in process streams throughout the ICB™. In addition, aqueous samples were taken to perform on-site and off-site analyses for selected chemical parameters.

For the purposes of validation, the ICB™ testing operations included the following types of emission and waste stream characterizations:

- Real-time monitoring of NO_x and SO₂
- Sample collection and off-site analysis of volatile organics, semi-volatile organics, anions, metals and particulate, dioxins/furans, hydrogen halides, hydrogen cyanide, ammonia, and hazardous waste characteristics

- Sample collection and on-site analysis for chemical agents, methane, NO_x, SO₂, and H₂S

To meet the objectives listed in Table 4-4, test phases were established for each of the systems as described in Table 4-8.

Table 4-8: Demonstration Test Phases for the HD ICB™ System

Unit	Test Phase	Description	Planned Duration	Test Structure
<ul style="list-style-type: none"> • HD/Energetic Hydrolysate ICB™ (note 1) 	Workup	Initiated with seven-day ramp-up after charging of feeds. Workup phase used to bring system up to steady state operations	20 days	<ul style="list-style-type: none"> • No validation sampling and analysis • Process monitoring conducted to fine-tune operation
	Validation	Steady state operation of ICB™ system	40 days	<ul style="list-style-type: none"> • Seven "test runs" for each system consisting of weekly liquid and gas sampling events • Daily process monitoring • Continuous monitoring of CatOx inlet and outlet for total hydrocarbons, CO, CO₂, temperature, and differential pressure

Notes:

1. Validation test interrupted due to operational problems

Source: Arthur D. Little, Inc.

The HD ICB™ unit was able to effectively remove Schedule 2 compound, thiodiglycol. The removal of thiodiglycol was greater than 99% in the biological unit. The CatOx unit worked effectively and did not show any signs of plugging or fouling, and there was no problem with agent in the offgas from the ICB™ or the CatOx. The only objective (Objective No. 5) that was met with reservation for the HD ICB™ was the development of data to be used for scale up. Four concerns were raised during the HD ICB™ testing: 1) the ability of the system to control the pH of the unit; 2) the need to control the concentration of salts and other compounds in the recycle stream; 3) the stability of the ICB™ organic removal over long term operations; and 4) the effective control of the biomass during long term operations. All four of these issues were the focus of the ICB™ testing performed during the EDS I Test Program (see Section 4.2.2, Parsons/Honeywell EDS I Test Program).

4.2.2 Parsons/Honeywell EDS I Test Program

HD ICB™. The HD ICB™ EDS I testing was performed at APG, Maryland in the same location and using the same equipment, with minor modifications, as Demonstration I testing. The system was modified to change the pH control strategy of the ICB™ cells; remove the Fenton's Reactor (found not to be needed during Demonstration I testing); remove the RO unit (found not to work during Demonstration I testing); and add an evaporator unit to concentrate the clarifier overflow and recycle the recovered water.

The system was operated in a manner similar to the Demonstration I testing with three major changes: 1) HD hydrolysate loading was increased from 40 gal HD Hydrolysate/day/1000 gal reactor volume to 50 gal HD Hydrolysate/day/1000 gal reactor volume during the test; 2) wood and wood/DPE condensate from the CST was processed through the ICB™ at a loading of up to 3 gal condensate/day/1000 gal reactor volume; and 3) the clarifier was bypassed and the ICB™ effluent was sent directly to the evaporator. The sampling analysis was the same as that conducted during Demonstration I testing, however, at a lesser frequency.

To meet the objectives listed in Table 4-5, test phases were established for the system as described in Table 4-9.

The HD ICB™ was able to effectively remove the Schedule 2 compound, thiodiglycol. The ICB™ was able to consistently remove thiodiglycol to a level greater than 99%. The ICB™ effluent chemical oxygen demand (COD) was consistently between 1000 – 1500 mg/L during the 130 day test period with a COD removal efficiency of 90 – 95%. The changes to the pH control system worked effectively and allowed the pH in each ICB™ cell to be controlled between 6 and 8. The biomass generation was as low in the EDS I testing as it was during the Demonstration I testing, and the ICBs™ did not show any pressure increase across the packing indicating that the packing did not become plugged during the testing.

CST condensate was fed to the ICB™ for a period of 74 days. During the CST condensate test, wood and wood/DPE condensate was fed to the unit at a rate up to 3 gal condensate/day/1000 gal reactor volume. The condensate addition did not impact either the ICB™ COD or thiodiglycol removal at the levels tested.

The CatOx operated effectively during the EDS I testing. However, water carryover caused a problem with corrosion and subsequent plugging of the CatOx preheater. The appropriate design of the full-scale ICB™ units should eliminate this problem.

The evaporator operated for two months with a feed from the clarifier overflow and for two months with a direct feed of ICB™ effluent without the clarifier. The ICB™ effluent feed did not appear to impact the evaporator; however, the quantity of biomass from the ICB™ did not visibly increase until the last 45 days of testing. The evaporator produced a brine that was near the saturation point for the dissolved solids (approximately a 90% reduction in volume). US Filter then performed tests on a small quantity of the evaporator brine and demonstrated that when the brine was concentrated an additional 50% significant salts were formed. To achieve adequate filtration of the solids, the addition of sulfuric acid to reduce the pH of the brine solution to a pH of 3.0 was required. The solids from the filter press were approximately 80% solids by weight.

Table 4-9: EDS I Test Phases for the HD ICB™ System

Unit	Test Phase	Description	Planned Duration	Test Structure
<ul style="list-style-type: none"> HD/Energetic Hydrolysate ICB™ 	Acclimation	Initiated with seven-day ramp-up after charging of feeds. Acclimation phase used to bring system up to steady state operations	20 days	<ul style="list-style-type: none"> No sampling for off-site analysis Process monitoring conducted to fine-tune operation
	Initial HD Hydrolysate Loading, No CST Condensate	Steady state operation of ICB™ system using a 40 gallon per day HD Hydrolysate Loading	55 days	<ul style="list-style-type: none"> Monthly liquid and gas sampling events for off-site analysis Daily process monitoring Continuous monitoring of CatOx inlet and outlet for total hydrocarbons, CO, CO₂, temperature, and differential pressure
	Initial HD Hydrolysate Loading, CST Condensate Loading	Steady state operation of ICB™ system using a 40 gallon per day HD Hydrolysate Loading CST Condensate Loading up to 3 gallons per day	45 days	<ul style="list-style-type: none"> Same as above
	Higher HD Hydrolysate Loading, CST Condensate Loading	Steady state operation of ICB™ system using a 50 gallon per day HD Hydrolysate Loading CST Condensate Loading up to 3 gallons per day	29 days	<ul style="list-style-type: none"> Same as above

Source: Arthur D. Little, Inc.

CatOx. Due to problems with the CatOx during the HD heel tests in Demonstration I testing, a long term test with direct HD injection into the CatOx was performed during the EDS I Test Program. The tests were performed at IIT Research Institute (IITRI) over a two month period. The tests were conducted with a standard CatOx unit and 10 mg/m³ HD injection rate. The HD destruction and removal efficiency (DRE) was determined across the CatOx.

The results of the testing demonstrated that the CatOx was able to consistently destroy the HD to below detection limits over the 600 hour test with a DRE of 99.9999%. During the test period, the HD DRE of the CatOx remained consistent, and the pressure drop across the unit remained relatively constant (1.6 to 4.6 inches of water). Based on this information, Parsons/Honeywell projected a life of the CatOx unit to be at least 30 months.

The CatOx test included corrosion coupons in the gas stream after the CatOx. Those corrosion coupons indicated that the Hasteloy C22 was an appropriate choice for materials of construction in the environment tested.

CST. The CST EDS I testing is being performed at CAMDS at Deseret Chemical Depot, Utah. The CST is a full-scale unit to decontaminate miscellaneous dunnage resulting from munitions accessing and other process wastes so that they meet the Army's decontamination criteria. This system is conceptually similar to the MPT that was tested during Demonstration I. The major difference is the size of the unit (MPT was a proof of concept and the CST is full-scale) and the manner in which the units are fed (the MPT was batch fed and the CST is continuously fed). Other than these differences the concept is the same.

The CST, as originally designed and constructed, had the same process flow diagram as the CST presented in the January 2001 Parsons/Honeywell Engineering Package. The unit is currently being modified to include a two stage cyclone between the CST and the reheater and a barrier filter after the quench tower based on the ongoing testing.

To meet the objectives listed in Table 4-5, test phases were established for the system as described in Table 4-10.

The CST EDS I testing is currently on hold to allow Parsons/Honeywell to modify the system to eliminate problems that occurred during the first part of the test program. Once these modifications are complete the final two test runs will be conducted. The current schedule is to finish these tests in July 2001.

During the first part of EDS I testing several issues arose that limited the operability of the CST unit as it was designed. The six major issues are:

1. Limestone aggregate caused serious plugging problems in the gas side equipment downstream of the CST. Limestone was replaced by carbon as the aggregate. Consideration was given to alumina; however, it was not chosen due to concerns about wear on the CST trough and auger.
2. A number of problems occurred with the designed feed system that caused the system to be shut down during operation. Repairs were made to the feed system and it appears to be operating more reliably now.
3. Significant particulate is generated in the CST and it has caused problems in the gas side equipment downstream of the CST including plugging of the lines and fouling of the CatOx catalysts. A single stage cyclone was added during the first part of the testing and it helped but it was not sufficient given the quantity of the particulate. The system is currently being modified to include a two stage cyclone before the reheater and a barrier filter before the CatOx preheater.
4. Significant quantities of dioxins and furans were found in the condensate and the pre- and post- CatOx gas streams. Parsons/Honeywell is currently reviewing the data from the first period of EDS I testing and is expected to modify the operating conditions to minimize the

formation of these compounds. Parsons/Honeywell has also proposed to treat the DPE separately from the wood in the final tests to limit the chlorine present when wood is treated.

5. Corrosion was observed in the gas stream piping and equipment (316 stainless steel) up to the quench tower. Corrosion coupon data from the first period of EDS I testing indicated that Hastelloy was an effective material. Based on this data, Parsons/Honeywell has replaced the gas side piping from the CST to the quench with Hastelloy.
6. The induction heaters caused a breach in the CST shell during systemization and in the reheater during testing. In both cases hot spots developed on the walls and caused them to fail. Unlike resistance heaters, induction heaters will not fail before the steel vessel they are heating do.

Table 4-10: EDS I Test Phases for the CST

Test Type	Feed Type	General Feed Characteristics	Length of Runs
Workup	None	Empty test chamber	1
Optimization Runs	Carbon	Clean granular activated carbon, 300 lb/hr	72 hrs
	Wood Pallets	Clean shredded pallets, 100 lb/hr	72 hrs
	DPE with boots and gloves	Clean DPE and butyl rubber , 15 lb/hr	72 hrs
	Wood and DPE	Clean pallets, 85 lb/hr, and Clean DPE, 15 lb/hr	72 hrs
Operability Runs	Wood and DPE	Clean pallets, 85 lb/hr, and Clean DPE, 15 lb/hr	250 hrs ¹
	Wood	Clean pallets, 85 lb/hr	125 hrs ¹
	DPE	Clean DPE, 15 lb/hr	125 hrs ¹

1. System was modified after the 250 hour Wood/DPE run to include a dual cyclone and barrier filter and to change out the stainless steel piping for Hastelloy between the CST and the quench tower.

Source: Arthur D. Little, Inc.

PWS. The Projectile Washout System (PWS) EDS I testing is planned to be performed at CAMDS at Deseret Chemical Depot, Utah with HD and HT 4.2-inch mortars. CAMDS would download the energetic components from the mortars using their PMD, and the PWS system would access the agent cavity, drain the agent, and washout the agent heels. The drained agent and washed out agent will then be hydrolyzed. The washed out mortar will be 5X decontaminated in an MPT.

The current design for the PWS is substantially different from the design presented in the January 2001 Parsons/Honeywell Engineering Package. The design presented in the Engineering Package is based on the use of a modified MDM followed by a Projectile Washout Machine. The MDM is modified to contain the mustard champagne effect and invert the munition after the burster well is pulled to drain the agent. The RWM uses high pressure water to washout the agent heel. For the EDS I PWS, Parsons/Honeywell has modified their approach to eliminate the burster well pull station for the 4.2-inch mortars and replace it with a system to cut off the mortar base plate and incorporate the Projectile Washout Machine as a station in the modified MDM.

Parsons/Honeywell has not proposed how this modified approach would handle the 105-mm and 155-mm projectiles. This information is expected as part of the Parsons/Honeywell EDS I PWS Final Technical Report.

The current schedule for the PWS is for the EDS I testing to be completed by the end of August 2001 and a Final Technical Report in September 2001.

5.0 Design Assessment

5.1 Objectives, Scope, and Approach

5.1.1 Objectives

The Design Assessment had four overall objectives with regard to review of the design itself and the supporting Engineering Package.

1. Consistency with the requirements of the disposal facility design as set forth in the Design Basis and the results of the Engineering Design Study I (EDS) testing.
2. Completeness in addressing all necessary aspects of the facility and, in particular, in terms of providing a “total solution”.
3. Core process viability in terms of operational efficacy and capability to consistently achieve both required levels of agent and energetics destruction as well as environmental performance.
4. Adequacy to support the +/- 20% cost estimate and to justify the proposed schedule (with modifications as required).

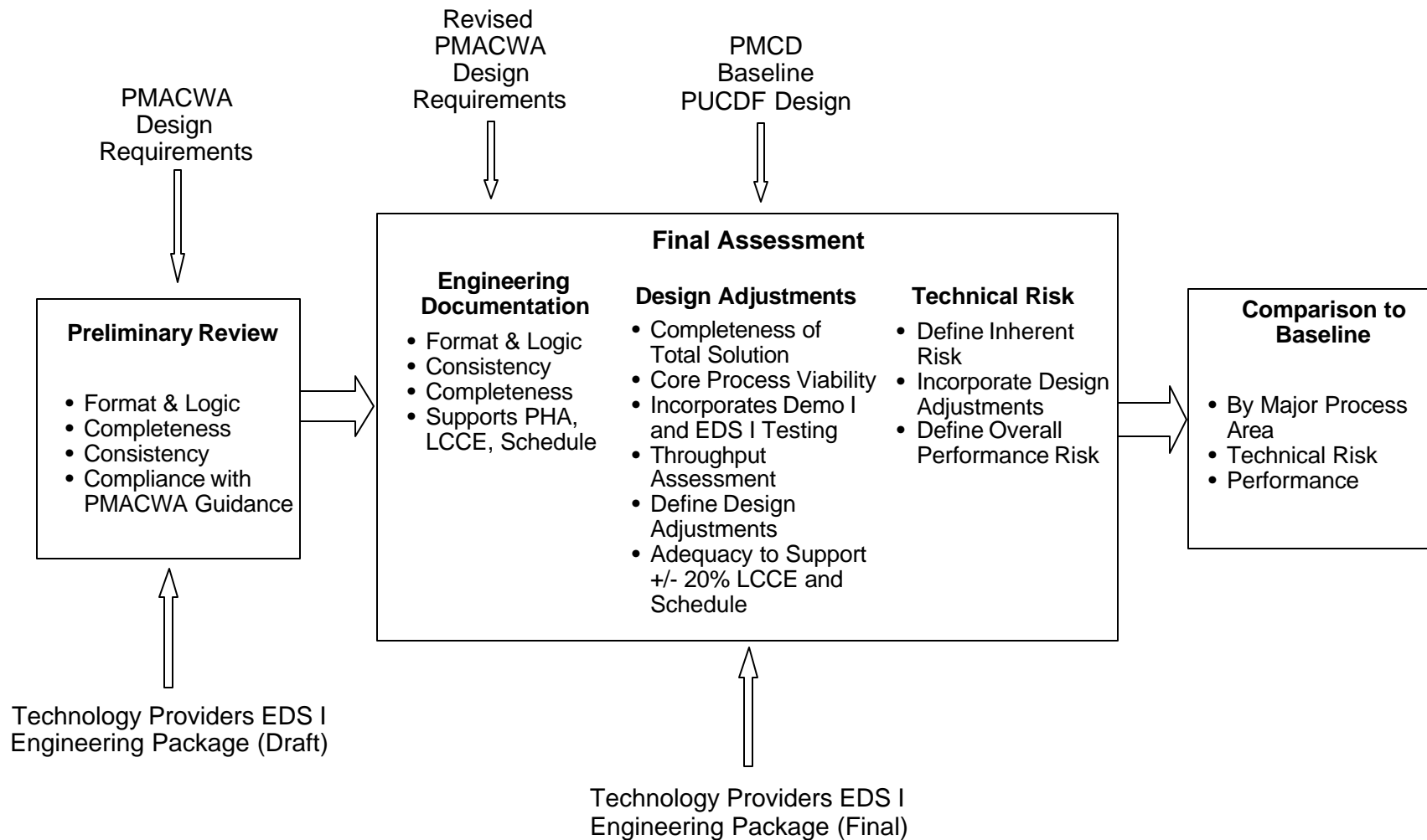
5.1.2 Scope and Approach

In order to achieve these objectives, the Design Assessment (see Figure 5-1) was conducted in concert with the Preliminary Hazards Analysis (PHA) Review, Schedule Assessment, and Cost Assessment as discussed in later sections. The coordination, and in some cases integration, of these activities was to ensure that the results would present a uniformity of concept and consistency in implementation.

It is recognized that the design package is still in the early stages of development and in many aspects has not yet attained a 35% level of completion. As such, the design package does not contain all design products needed to verify detailed design adequacy. Specifically, lack of supporting calculations and analyses require the assumption of correctness of information included in the package. Therefore, it is important to recognize that the Design Assessment does not constitute a “design review” in the traditional sense. There have been no structured, detailed discipline reviews of design studies or drawings. The design package would not support such a review, nor would such a review be warranted at this stage. However, where rudimentary checks could be performed to validate data or design results without the governing calculation, they were performed. Important examples include verification of the throughput core process and capacity of auxiliary and ancillary systems.

The Design Assessment focused on the following aspects of the Water Hydrolysis Energetics and Agent Technology (WHEAT) design:

- Shares common elements of overall plant design basis and assumptions with those of the Baseline.
- Contains all the processing units necessary for munitions handling and treatment of agent, energetics and dunnage as well as all emissions, effluents and wastes to the extent required.
- Incorporates all design concepts derived from and consistent with the results of the testing conducted under Demonstration I and the EDS I Test Programs.

Figure 5-1: Design Assessment Methodology

- Provides sufficient definition of the design and operating parameters of the major core process equipment and equipment interfaces to support a Throughput Assessment.
- Incorporates equipment selection and configuration (including layouts) that offer ease of operation and maintenance.
- Provides definition of equipment and facilities in sufficient detail to support the cost estimate.
- Delineates operating and control philosophy in sufficient detail to support the PHA.
- Provides all necessary information to support the assessment of environmental impacts required for the National Environmental Policy Act (NEPA) documentation and the Resource Conservation and Recovery Act (RCRA) Part B permit application.
- Projects comparable, if not enhanced, performance relative to Baseline.

It should be noted that, where design weaknesses or inconsistencies were identified, compensating design adjustments have been made for cost estimating purposes. These include equipment enhancements, replacements and additions as well as modifications to facilities (e.g., buildings). These changes have not been incorporated in the Parsons/Honeywell Engineering Package, but are included and discussed in this report.

The results of the assessment are discussed in two parts. The first part is the documentation provided in the Engineering Package provided by Parsons/Honeywell. The second part is the design of the core process itself and the principal auxiliary subsystems.

5.2 Engineering Documentation

Table 5-1 lists the engineering documentation (broken down by discipline) that was required to be provided by Parsons/Honeywell as a part of their Engineering Package. Table 5-1 also indicates if the documentation was included in the January 2001 Engineering Package submittal.

The design package includes three major categories of documents:

- Basic Process Engineering Documents – These are the key engineering documents that define the overall process requirements, which then form the basis for detailed design, procurement, and construction. These documents are the focus of the Design Assessment.
- Safety Analysis Documents – The Preliminary Hazards Analysis and the Fire Hazards Analysis included in the package are semi-quantitative in nature and will evolve with the design. Their use at this stage of the design provides assurance that plant hazards have been identified for resolution. It is not expected that the defined resolutions have been incorporated into the design.
- Production Documents – These documents support the construction effort and are used in the package primarily to support both cost and schedule estimating.

Table 5-2 illustrates both the relationship of the documents to different facets of the design package as well as how they were used in the assessment efforts.

Table 5-1: Engineering Design Package Submittals

Included in Submittal	Engineering Package Requirements*		
	Drawing/Document	Level of Completion	Comments
Process & Mechanical			
Yes	Process (and Facility) Design Basis	F	Defines: performance requirements; raw material and utilities characteristics
Yes	Process Flow Diagrams	C	Complete for all systems within the scope of supply (Rev 0)
Yes	Material & Energy Balances	C	By campaign - sustained maximum and annual average conditions
Yes	Water Balance Diagram	C	With flows for sustained maximum and average conditions
Yes	Throughput Analysis	C	Preliminary analysis of the availability and reliability of process subsystems and/or major pieces of process equipment to support equipment sizing, configuration and schedule
Yes	Process Description	C	Preliminary description including overall operating and control philosophy
Yes	Emissions and Effluents Lists	C	Characteristics & quantities of air emissions, water discharges & solid wastes
Yes	Equipment Lists	C	Major equipment with dimensions, capacities, materials, & preliminary loads
Yes	P&IDs	C	Shows line sizes and materials; primary instruments; control interconnects
No	Major Equipment Specifications	P	Data sheets/equipment specifications to support PHA and costs
Yes	General Arrangements	P	Basic plans and sections showing location of major equipment
Yes	Tanks/Vessels Data Sheets	P	Dimensions, capacities, materials, internals, pressure and special requirements
In P&IDs	Line Lists/Piping Schedules	P	Not required if pipe sizes and materials are given on P&IDs for major lines
Yes	Process Hazards Analysis	P	Preliminary for the core process plus adjustments as required to that prepared for the Baseline
Yes	Fire Hazards Analysis	P	
Civil, Structural & Architectural			
Yes	Site Development/Drainage Plan(s)	P	Only as required to support cost estimates (or PHAs), especially if new buildings are proposed or there are significant modifications to existing Baseline buildings
Yes	Plot Plan(s)	P	
No	Foundation Designs/Studies	P	
No	Structural Steel Designs	P	
Yes	Building/HVAC Designs	P	

Table 5-1: Engineering Design Package Submittals (continued)

Included in Submittal	Engineering Package Requirements*		
	Drawing/Document	Level of Completion	Comments
Electrical			
Yes	Motor Lists	C	Complete
Yes	Major Equipment Lists	C	Complete
Yes	Electrical Area Classifications	P	Complete
Instrumentation & Controls			
In P&IDs	Loop Definitions/Functional Descriptions	C	In sufficient detail to support preliminary PHAs and operability analyses
Yes	Instrument Lists	P	Principal instruments by type and function
Yes	Control System Mini-Specifications	P	Basic requirements for central control panels & DDCS System to support costs

* U.S. Army SBCCOM: Statement of Work, Engineering Design Package

P - Preliminary (Sufficient to support PHA and cost estimate)

C - Complete (Full set of drawings for major eq't/systems, but not yet fully detailed)

F – Final

Source: Arthur D. Little, Inc.

5.2.1 Basic Process Engineering Documents

The Basic Process Engineering Documents together provide a complete, concise description of the process and facilities; establish design criteria and design basis information; provide engineered definition to each system; and specify/repackage the criteria and bases to support detailed design development (presented in production drawings), procurement, and permitting. The Design Assessment focused on these drawings and documents. Commentary is provided below.

Process (and Facility) Design Basis. A Design Basis should clearly and succinctly identify design criteria and requirements as the highest level input to the design. These criteria and requirements should include: site-specific conditions; battery limits interfaces and constraints; performance objectives; applicable industry, discipline, and government codes, standards, and documents; design philosophies (e.g., equipment sparing); and possibly contractor developed or client imposed operating parameters and bounding conditions (e.g., use of certain technologies, processes or design parameters).

Overall, the Parsons/Honeywell Design Basis is much too expansive. It encompasses the Throughput Analysis, process system and facility descriptions, facility fire protection design analysis, process flow diagrams and process control concepts. All of these should be prepared as separate documents. This considerable amount of unrelated, descriptive material makes it extraordinarily difficult to use because it is nearly impossible to identify the important elements that are critical to the design effort. In addition, there are a number of omissions from, or errors in, the Design Basis. Related observations include:

Table 5-2: Utilization of Engineering Documentation

Drawing/Document	Design Assessment	PHA Review	Cost Assessment
Basic Process Engineering Documents			
Process (and Facility) Design Basis	●	●	●
Process Flow Diagrams	●	○	○
Material & Energy Balances	●	○	●
Water Balance Diagram	●		○
Throughput Analysis	●		●
Process Description	●	●	○
P&IDs	●	●	○
Control System Philosophy	●	○	
Process Equipment Lists	●		●
Tanks/Vessels Data Sheets (Lists)	●		●
General Arrangements	●	○	●
Emissions and Effluents Lists	●		●
Safety Analysis Documents			
Process Hazards Analysis		●	
Fire Hazards Analysis		●	
Electrical Area Classification Plan		●	
Production Documents			
Major Equipment Specifications	○		●
Site Development/Drainage Plan(s)			○
Plot Plan(s)	○		●
Foundation Designs/Studies			○
Structural Steel Designs			○
Building/HVAC Designs			○
Motor Lists			●
Electrical Equipment Lists			●
Instrument Lists			●
Control System Mini-Specifications			●

Key: ● Primary information source
○ Secondary information source/reference

Source: Arthur D. Little, Inc.

- Some important site-specific conditions have not been defined. While there are several Baseline documents that support and complement the Design Basis by reference and serve as alternative sources for this information, there are notable omissions. Examples include: assumptions regarding the source, quantity and quality of raw water available upon which water treatment system designs are predicated; location-specific (state and local) environmental requirements; and assumptions regarding climatological conditions used in developing cooling water requirements and preparing water balances.
- Not all government design requirements have been included. For example, a number of important secondary wastes that need to be treated have not been included in the design.
- Where the Design Basis identifies design parameters, a source reference or justification is generally not included. No discussion of risk and acceptable bounding conditions was provided should the parameter prove to be incorrect.
- Specific design parameters developed through government testing for hydrolysis of agent and energetics are not clearly articulated nor adequately referenced. These are a prerequisite for all designs utilizing hydrolysis-based systems.
- It is not noted that EDS I testing of some system components (e.g., the Continuous Stream Treater [CST] or Rotary Washout Machine [RWM]) had not been completed prior to submittal. New results and lessons learned need to be factored into the design. They will impact equipment selection and system performance, mass and energy balances, effluent summaries, and environmental permitting consideration.

The Design Basis needs to be tailored to the Pueblo site and address all site requirements. Of equal importance is the clear statement of government-imposed requirements. Arthur D. Little did not perform a detailed design review of industry and discipline codes and standards or Corps of Engineers Technical Manuals to determine whether the list is complete and appropriate. The importance of this list will increase as the design progresses.

In summary, the Design Basis needs to be revised to improve the completeness and accuracy of requirements provided and the source of those requirements. Nevertheless, the inadequacies of the Design Basis do not preclude an assessment of the design.

Process (and Facility) Descriptions. The Process and Facility Descriptions were presented as part of the Design Basis. While these documents adequately describe how systems are configured and how the components would function, there are some deficiencies as noted below.

- There is a lack of identification of reference or source documents for many parameters. No supporting calculations or references are identified, and there are no supporting calculations or trade-off studies justifying selection of equipment. Rudimentary checks were made by Arthur D. Little to verify the use of many of these parameters. The lack of supporting calculations and/or other justification, however, did hamper the design assessment.
- Where design parameters are not sourced or justified, no discussion of risk and acceptable bounding conditions have been provided should the parameter prove to be incorrect.
- There is some inconsistency in the level of detail provided. For example, there is little detail provided for operations upstream of the PMDs and for the Brine Reduction System (BRS).

- Many secondary flows have not been included in the descriptions or are not well categorized.
- Start-up, shutdown and upset conditions have not been addressed to the extent that it is clear that the design of the subsystems or process units incorporate the necessary provisions to accommodate upstream and downstream interfaces and that supporting utilities are properly sized.

Significant revision to these documents is required to provide source, reference, and supporting justification and to completely describe each system. Supporting calculations are needed to ensure the equipment has been adequately sized.

Process Flow Diagrams (and Utility Diagrams). Process Flow Diagrams (PFDs) and Utility Diagrams (UDs) should present the logical construct of each (sub)system by identifying all major pieces of equipment and equipment interconnections as well as connections between subsystems. In this regard, the flow diagrams generally provide an adequate definition of each (sub)system, although, there is considerable variability as well as inconsistencies and omissions, as noted below.

- Utility Diagrams were not provided.
- Mass flow tables at the bottom of each PFD exhibit flawed logic in some areas and contain errors and unit designation problems.
- There are some inconsistencies with drawings provided as a part of vendor packages.
- Not all utilities have been included.
- Not all emissions streams have been identified (e.g., cooling towers, boilers).
- There is no PFD for the Munitions Demilitarization Building (MDB) Heating, Ventilation, and Cooling (HVAC) filtration system.

Material and Energy Balances. The Parsons/Honeywell Material and Energy Balances present what are described to be design and steady state cases. However, there are noteworthy omissions and inconsistencies.

- The design cases are presented on a system-wide basis; however, they show design rates that the entire system cannot handle. It would have been better to provide design cases on a subsystem or component level.
- As is the case for the PFDs, a number of air emissions streams are not included, such as: air discharges from building vent systems (MDB Filters, SCWO Building); cooling tower drift; and boiler flue gases.
- Again, as discussed with the PFDs, a number of utility streams are not included.
- There are omissions of component flows in several balances. For example, the CST balance does not include aggregate.

The Material and Energy Balances will require updates to incorporate the missing streams identified above, correct minor inconsistencies, and accommodate changes associated with ongoing EDS I testing as well as design evolution such as related to the design changes recommended in Section 5.3, Key Issues and Resolutions.

Water Balance Diagram(s). The Water Balance Diagram serves three purposes. First, it is to ensure that sufficient attention has been given to the water balance so that the goal of a zero water discharge facility can be appropriately factored into the overall design. Second, it supports the Throughput Analysis in demonstrating that the coupling and decoupling of operations incorporates adequate surge and storage capacity both for routine operations as well as startup/shutdown requirements and anticipated upset conditions. And finally, the balance serves as a check point for completeness and accuracy of the overall material and energy balances.

The water balance provided is very difficult to navigate and understand. A close examination of the balance requires excursions through the Design Basis and numerous PFDs and P&IDs. From such an analysis, it is clear that there are several streams and/or systems that have not been included, such as the cooling tower. In addition, the balance is only for steady state conditions; however, excess water is generated for which the duration is unstated. Finally, no water balances have been prepared for seasonal variations or startup and shutdown conditions. Consequently total make-up water requirements are not well defined.

Updates and revisions to the water balance diagram are required to incorporate all water requirements and conditions when large fluctuations can be anticipated. However, the balance provided was determined to be adequate for overall assessment of the design including what additional requirements might be necessary to handle surges. This is discussed in more detail in Section 5.3, Key Issues and Resolutions.

Throughput Analysis (and Time and Motion Study). A Throughput Analysis is required to demonstrate that, based on equipment and system availability, reliability, and capacity, plant operations will meet both performance objectives and the proposed schedule. The Parsons/Honeywell Throughput Analysis is presented in the Design Basis and is supported by the Time and Motion Diagram. The Throughput Analysis, though, is incomplete, internally inconsistent, and lacks justification. This is considered a major deficiency in the Engineering Package and is a key issue discussed in more detail in Section 5.3. Notable problems with the Throughput Analysis are summarized below.

- The scope of the analysis is quite limited. It only considers munitions handling and disassembly, agent processing, the Rotary Metal Parts Treater (RMPT), and the ICBs™. It does not incorporate other important process systems including the CST and its offgas treatment system, the combined offgas treatment system for the Batch Metal Parts Treater (BMPT) and RMPT, and the Brine Reduction System (BRS). In the design submitted, all of these are single, non-redundant subsystems which will undoubtedly have a significant impact on overall plant availability and operating capacity.
- The availabilities, reliabilities, and capacities assumed for most equipment and process systems are not justified. For example, the RMPT is incorporated in the analysis as an integrated part of the overall disassembly area rather than a separate, serially processing path.

The RMPT is a single unit that could shut down the entire disassembly area, but there was no indication of its independent availability or reliability.

- There are numerous errors of logic and mathematics in the analysis.
- There is little attention paid to the constraints or flexibilities presented by surge capacities between interfaces of decoupled equipment units.

Therefore, to evaluate the design, it was necessary that Arthur D. Little undertake a new, independent Throughput Analysis. This revised analysis, as discussed in Section 5.3, was used to identify required adjustments to specific equipment capacities, numbers, size, and operating schedules. While the analysis prepared by Arthur D. Little is considered sufficient to complete the Design Assessment, a more thorough analysis must be prepared prior to continuation of a detailed design effort.

Piping and Instrumentation Diagrams (P&IDs). The P&IDs were used primarily in the review of process operability and performance of the PHA review. In general these were found to be satisfactory; however, a complete set of P&IDs was not provided. There are no P&IDs for the BRS as well as a number of the utility water systems such as demineralized water distribution and some cooling water systems.

Control System Philosophy. The Control System Philosophy was utilized in conjunction with the process descriptions and P&IDs. It is considered adequate for normal operations and provides a rudimentary sequencing for startup, shutdown and steady state. However, a more expansive discussion of the provisions for interfaces between subsystems during startup, shutdown and upset conditions would be useful, especially in concert with the Throughput Analysis.

Process Equipment List. The Summary Equipment List is generally complete for all but equipment supplied as a part of vendor packages (e.g., BRS, water treatment, utility systems). The information provided is not always complete but is sufficient for the Design Assessment and cost estimating purposes. The largest deficiency in the equipment lists is the identification of the materials of construction. There are numerous examples of internal inconsistencies in materials selection (e.g., valves) or selection of materials that are either inconsistent with type of equipment (e.g., lining of very small units) or the equipment service.

Tanks/Vessel Data Sheets. Data Sheets for the Tanks and Vessels were provided in the package. These sheets provided sufficient information to perform the design assessment.

Building Arrangement Drawings. Three new buildings of significance have been proposed in the WHEAT design, the MDB, the Process Auxiliaries Building (PAB) and the Utilities Building (UB). Arrangement drawings for these were used primarily in the Cost Assessment for comparing and reconciling estimates for different facilities and developing costs for recommended expansions to accommodate additional equipment. In the Design Assessment, they were also used in evaluating space allocations for operations and maintenance access. However, no drawings were provided for the Utilities Building (UB).

Emissions and Effluents List. The Emissions and Effluents List provided by Parsons/Honeywell is basically a material balance-level document that lacks details in

characterizations of most streams. It also is incomplete in identifying all point source and potential fugitive emissions and effluents. The following deficiencies were noted.

- Incomplete characterizations – Many of the streams lack complete characterizations, particularly at the trace levels for contaminants of interest. Characterization data from the EDS testing complemented process knowledge and engineering judgement need to be factored into all streams shown in the Emissions and Effluent List
- Omitted Streams – Numerous streams are not included in the Effluents and Emissions List. These are primarily solid wastes and air emissions since the design is predicated upon zero wastewater discharge. Examples of air emissions that have not been included are volatile organic compounds from fuel storage, evaporation and drift from cooling towers, and boiler flue gas. Many solid wastes are also not addressed, including both process-related wastes (e.g., spent hydraulic fluids and other wastes generated by maintenance activities) and non-process wastes (e.g., trash and sanitary wastes). One possible liquid waste that has been identified is boil-out from BRS evaporator maintenance. This water cannot be readily returned to the system because of the scale potential within the BRS itself. It is expected that it would have to be disposed off site.

It is recognized that this is a preliminary listing, but it must be complete to the extent information is available. This is considered a significant deficiency in the Engineering Package. A full list of effluents, emissions, and wastes must be prepared to support the preparation of the environmental permit and cost estimating.

5.2.2 Safety Analysis Documents

The Preliminary Hazards Analysis, Fire Hazards Analysis and Electrical Area Classification Plan were used primarily in conjunction with the PFDs, P&IDs, and selected other drawings such as Building Arrangements for conducting the PHA review. These were generally found to be consistent with this phase of design and adequate. The PHA is discussed in Section 6.0, Preliminary Hazards Analysis Review.

5.2.3 Production Documents

For this level of review, the following drawings have been identified as Production Drawings. They are mainly used to support cost estimates, although a number would certainly also be part of environmental permitting submittals. These include:

- Engineered Diagrams (Electrical Single Lines, HVAC, Instrumentation);
- Equipment Outline and Design Specifications for Major Process Equipment;
- Equipment Details, Interface Control Drawings, and Specification Control Drawings;
- Summary Motor Load List;
- Summary Instrument List and I/O Count;
- Site Plot Plans;
- Structural and Foundation Drawings; and
- Building Architectural Drawings.

Most of these are adequate for the use intended. However, it is noteworthy that only minimal process equipment specifications (with the exception of Data Sheets for the Tanks/Vessels) were submitted.

5.3 Key Issues and Resolutions

Arthur D. Little's review of Parsons/Honeywell Total Solution (WHEAT) design submittal was intended to determine the adequacy of the design in supporting capital and operating cost estimates and the proposed schedule. Part of the Design Assessment included the following steps:

- A review of the submitted documents to evaluate the feasibility of the overall WHEAT process design and the ability of the system to process the munitions according to the submitted cost estimates and schedule.
- Adjustment of the process to "fix" design errors and flaws noticed in the review of documents. The focus was on major problems that would affect capital and operating costs and schedule.
- Adjustment of the process to assure adequate throughput, mainly by increasing reliability and capacity. The focus was on plant components that were potential bottlenecks that would extend the schedule and increase life cycle costs.
- Adjustments to the process to address results from the ongoing EDS I testing in support of the WHEAT design. The purpose of these adjustments was to incorporate information produced from EDS I testing subsequent to the January 2001 Engineering Package submittal, and to reduce the perceived risk from uncertainties still remaining due to the additional EDS I testing that will be completed after 31 March 2001.
- Adjustments to the process to reflect changes to the WHEAT design basis made by PMACWA in response to questions that arose out of the design assessment.

This section discusses the key design issues and the resolutions made by Arthur D. Little as a consequence of the assessment steps described above, and an analysis of the technology risks still remaining in the WHEAT process.

Because the WHEAT process is integrated, it was difficult to present a clear *a priori* precedence order of issues. Table 5-3 presents a summary of the major issues in the order in which they were identified and discussed during the review. Table 5-3 also includes the potential options and the action items taken on these issues with respect to cost and schedule adjustments. The following discussion presents the key design issues in order of importance with respect to their effects on the design, costs and schedule, after the issues were resolved. Issues that did not require modifications are discussed last. The discussion is referenced back to the numbering system used in Table 5-3 by the number in parentheses at each heading.

Table 5-3: Issues from the Design Assessment

Issue Area	Issue Description	Options for Modification or Adjustment	Resolution
1. Throughput Analysis	The Throughput Analysis is flawed due to unsubstantiated assumptions and incomplete analysis. It does not support the proposed schedule or capacity decisions. No calculations are provided.	An assessment was undertaken to identify required adjustments to specific equipment capacities, number, operating schedule, etc. The assessment also placed WHEAT, GATS, and Baseline on the same basis so they could be compared	The results of the assessment have been incorporated into the adjusted subsystem. See Items 2(a), 3(d), 5(a) and (b), and 8(a).
2. PMD, MDM & RWM			
a. PMD & MDM coupled operation	In the WHEAT design the PMD and MDM were coupled together because no buffer storage was provided.	1. No action 2. Add buffer storage similar to Baseline 3. Add an additional MDM/RWM	Buffer storage was added between the PMD and the MDM. The buffer storage is approximately 8 hours. An additional MDM/RWM was added to improve availability of reverse assembly.
b. MDM & RWM coupled operation	The MDM and RWM have never been run together, so there may be interface problems that delay systemization and pilot testing or independent failure modes that could impact overall availability.	1. Extend the systemization schedule. 2. Extend the Pilot Test schedule. 3. Extend the O&M schedule. 4. Any combination of the above.	The schedule extension for Pilot Testing from six months to one year is deemed to be adequate to resolve any such problems.
c. MDM - champagning issue	Resolution of the champagning problem with HD has yet to be demonstrated.	The burster well pull will be enclosed to contain any agent spray.	No action required.
d. MDM - pulling burster wells	The cutting/grinding step on the MDM was eliminated thereby potentially rendering pulling some burster wells impossible.	Reinstitute the cutting/grinding step on the MDM.	Cutting step reinstituted.
e. RWM - agent heel removal	There may be potential for significant carry forward of agent in the munitions. 2% carry forward has been assumed by Parsons.	1. No action. 2. Testing should demonstrate that water temperature, quantity or pressure resolves issues. 3. Design RMPT (or alternative BMPT) for higher agent loads.	Testing to determine the agent heel remaining after washout will be completed by August 2001. A review of the PAS equipment downstream of the RMPT indicates that it could handle up to 50% agent heels. No action was taken.
f. RWM - agent heel biodegradability	There may be production of low to non-biodegradable byproducts as well as constituents which could be toxic to the organisms. This should be checked per ABCDF results.	1. No action. 2. Add more ICB™ capacity (to allow longer contact time). 3. Dilute and add both additional ICB™ and BRS capacity. 4. Perform lab tests if the agent heel is significantly larger the ABCDF test.	ACBDF has performed biotesting on HD hydrolysate with agent heels of up to 27%. The results show that the organic removal efficiency drops off as the agent heel get larger. Lab testing should be considered during EDS I testing if the HD heel in the mortars is found to be significantly greater than 27%. See 7(c).
g. Materials of construction	Use of epoxy-coated materials may not be rugged enough vs. metallics.	Add costs for using titanium or Hastelloy C276 rather than epoxy-coated steel.	Covered in Materials of Construction contingency.

Table 5-3: Issues from the Design Assessment (continued)

Issue Area	Issue Description	Options for Modification or Adjustment	Resolution
3. RMPT			
a. Materials of construction	Adequacy of materials of construction specified for the full-scale design need to be checked against the EDS I test results.	Hastelloy C276 was shown to be adequate in the CatOx and CST EDS testing. Both of these test were tested in a steam environment with high concentrations of chloride. Very similar or worse environment than the RMPT gas stream.	No action required.
b. Mechanical performance	The mechanical performance of the unit has not been demonstrated.	Switch to a BMPT design with processing of rounds in an upright orientation.	See Item 3(d).
c. Agent decontamination	Manner of loading and processing rounds (horizontally, end-to-end) may not allow complete agent release. How much agent heel can be tolerated has not been determined.	Switch to a BMPT design with processing of rounds in an upright orientation.	See Item 3(d).
d. Availability	An unrealistically high reliability appears to have been assumed in the availability analysis.	<ol style="list-style-type: none"> 1. Switch to BMPT(s) 2. Add another RMPT of equal capacity. 3. Use two slightly smaller RMPTs (e.g., two @ 75%). 4. Extend the schedule. 	Assume two RMPTs @ 100% of required capacity. The cost of these is greater than equivalent BMPTs and will allow the flexibility to change during detailed design without cost growth.
4. BMPT			
a. Availability	Validity of capacity/availability assumptions need to be verified.	The BMPT capacity and availability are sufficient.	No action required.
b. Treatment of fines from CSTs	CSTs will produce additional particulate waste from the cyclones and filters that must be decontaminated to a 5X level.	The quantity of particulate from the CST is low and will require only one additional tray to be treated per day. Based on the Design Assessment the BMPT has sufficient capacity to handle the particulate waste.	<p>No action required.</p> <p>See Item 9(b).</p>
5. Agent Neutralization			
a. Hydrolyzer capacity	Agent neutralization capacity may not be adequate due to the Design Assessment adjustments.	<ol style="list-style-type: none"> 1. Increase agent hydrolyzer capacity. 2. Add a fourth train. 3. Extend the schedule. 	The capacity of the Agent Hydrolysis reactors was increased by 33%.

Table 5-3: Issues from the Design Assessment (continued)

Issue Area	Issue Description	Options for Modification or Adjustment	Resolution
b. Agent storage and feed capacity	The agent and agent concentrate storage are not adequate given the Design Assessment adjustments. Additional storage capacity will also further decouple Agent Hydrolysis from reverse assembly.	1. Add additional storage capacity to increase buffer 2. Add additional feed equipment	Added cost for second Agent Storage Tank, Agent Concentrate Storage Tank, and Agent Surge Tank and associated pumps, piping, and instrumentation. Consideration needs to be given to how much agent can be stored without causing a safety issue.
c. Hydrolysate release criterion	The Parsons Design Basis (page 3-14, 2nd paragraph) states that the agent concentration must be less than 330 ppb in order to release a batch of agent hydrolysate. The ABCDF criterion is non-detect with an MDL of less than or equal to 20 ppb.	This appears to be a typographical error. The PMATA and PMACWA testing have shown that the mustard concentration in the final hydrolysate is below detection limits. The WHEAT Agent Hydrolysis process should meet that level as well.	No action required.
d. pH adjustment	ABCDF has modified their batch cycle to adjust pH prior to sample collection rather than after HD analysis has demonstrated agent destruction. This change is not reflected in the Parsons Design Package.	This modification does not impact the batch cycle time or equipment requirements and therefore, should not impact cost and schedule. This change and others resulting from ongoing neut/bio testing by ABCDF should however, be addressed in future Design Packages.	No action required.
6. Energetics Hydrolyzers	Is there adequate time in the batch schedule to accommodate energetics analysis (NC & NG) turnaround times and to handle offspec production?	The Energetic Hydrolysis system has significant excess capacity; therefore, analytical turnaround time should not be a problem.	No action required.
7. ICB™			
a. EDS Testing does not match full scale design	Hydrolysate loading to the ICBs™ in the EDS Design Package appears to be higher than that in the EDS Testing.	Detailed evaluation of material balances indicates loadings are within tested values.	No action required.
b. Propellant biotreatment	The propellant ICB™ test has not been completed.	EDS I test results show that at least partial biodegradation can be achieved 30-40% COD removal for the M1 and 70 – 80% removal for the M8. The full scale ICB™ design provides considerable excess capacity compared to the test parameters. In addition, propellant processing may not be a part of the demil operations if munitions are reconfigured by the Depot.	No action required.

Table 5-3: Issues from the Design Assessment (continued)

Issue Area	Issue Description	Options for Modification or Adjustment	Resolution
c. Biodegradability of hydrolyzed agent heels	The quantity of heel in the munitions has not been determined and the biotreatment testing of the combined drained agent and heel hydrolysate has not been conducted.	<ol style="list-style-type: none"> 1. No action. 2. Add more ICB™ capacity (to allow longer contact time). 3. Dilute and add both additional ICB™ and BRS capacity. 4. Perform lab tests if the agent heel is significantly larger the ABCDF test. 	No action required. ACBDF testing indicates that ton container heel materials can be effectively biotreated with agent hydrolysate. If the ratio of heel to drained agent in the munitions is much greater than that tested by ABCDF and or the composition of the heel differs from ton container heels however, additional testing may be required.
d. HT hydrolysis and biodegradability	Is the full scale design adequate to handle the hydrolysis of HT and biotreatment of HT hydrolysate?	ECBC Testing has shown that HT is hydrolyzed at the same rate as HD and biotreatment is comparable to HD hydrolysate.	No action required.
e. Impact of dioxins and furans	Will dioxins and furans have any deleterious impacts on the performance of the ICB™? Or is there potential for formation of dioxins and furans in the ICB™ CatOx?	No deleterious impacts identified. The dioxins and furans were shown to remain in the liquid and pass through the ICB™. Test results indicate that there are essentially no dioxins and furans going to or formed in the CatOx.	No action required.
8. BRS			
a. Availability	There is only one BRS train and its reliability and operability have not been tested or adequately justified; thus, it may be a significant availability or even overall performance "pinch point".	<ol style="list-style-type: none"> 1. Add a duplicate train. 2. Install two smaller trains. 3. Larger capacity with more storage buffer. 4. Use (viability of) offsite liquid HW disposal. 5. Use offsite NHW disposal (is it delisted?). 	Convert to two complete 75% BRS trains. This will affect the cost of the BRS system, the cost of the PAB to accommodate this equipment, and the cost of the electrical supply systems.
b. Performance with propellant hydrolysate	It cannot be determined whether there are any performance issues related to processing the organics in the BRS since this was not tested.	<ol style="list-style-type: none"> 1. Use evaporator alone and dispose of concentrate. 2. Provide for operation at reduced loadings. 3. Provide redundant trains. 	This issue is presumed to have been resolved by the additional BRS capacity per Parsons-8(a). Having 2 x 75% equivalent BRS trains is expected to provide more than adequate capacity to treat the propellant ICB™ effluent. This issue becomes moot if munitions are reconfigured prior to munitions destruction.
c. Dioxins/Furans impacts from CST condensate	Testing has shown that dioxins and furans are being generated in the CST due to the treatment of wood and DPE at the current design temperature. If these compounds are produced in the full-scale CST, they will be present in the CST condensate and pass untreated through neutralization and biotreatment to the BRS.	<ol style="list-style-type: none"> 1. Redirect the BRS vent to a dedicated carbon filter to remove dioxins and furans in the vent stream. 2. Modify the CST operating temperature to preclude production of dioxins and furans. 	The BRS vent was redirected to a new dedicated carbon filter with air dilution to reduce humidity.

Table 5-3: Issues from the Design Assessment (continued)

Issue Area	Issue Description	Options for Modification or Adjustment	Resolution
9. CST			
a. Dioxins/Furans	Testing has shown significant levels of dioxins and furans in liquids and solids downstream of the CST. The fate and effects of dioxins and furans on the ICB™ or on waste streams has not been demonstrated or determined.	<ol style="list-style-type: none"> 1. No Action. 2. Change CST operating conditions (e.g., higher pH, quenching). 3. Replace CST with unit operating under reducing conditions. 4. Add dedicated carbon filters and split from main HVAC. 5. Address impacts in downstream equipment (e.g., ICB™, BRS). 	The CST design was adjusted to switch the CatOx gas discharge from the main HVAC to dedicated carbon filter units. A quench tower was also added to cool the gas stream prior to the carbon filter. The impacts in condensate will be handled in the downstream equipment. Also see 7(e) and 8(c). Ongoing EDS I testing will examine adjustments to the CST operating conditions to reduce the formation of dioxins and furans.
b. Particulate impacts/emissions	Fine particulate causes foaming of the quench and possible plugging of the CatOx. Particulate in the full scale could be even greater due to higher wood throughput.	Install dual cyclones followed by a barrier filter. Need to assess the frequency of candle filter replacements on O&M costs and availability/schedule.	Add capital and operating costs for two 100% capable trains each containing dual cyclones and a barrier filter. Costs to include gas handling upgrades (fans, ducting, etc.). 100% capacity capability is based upon the sizing determined in 9(i).
c. EDS testing does not match full scale design	<p>The full scale design does not match the conditions utilized/planned in the EDS testing in the following respects:</p> <ul style="list-style-type: none"> • carrier material (alumina in full scale vs. carbon in planned EDS Testing). • steam use is 1/4-1/3 that of EDS testing. • use of nitrogen in full scale design. 	<ol style="list-style-type: none"> 1. Retain use of activated carbon with higher makeup rate to account for fines production. 2. Assess/readjust equipment sizing as required. 	<ol style="list-style-type: none"> 1. Assume continued use of carbon for the full scale plant. Carbon makeup rates of 5% will be used for operating costs (i.e., 10 lbs of carbon per 100 lbs of wood; and 45 lbs of carbon per 100 lbs of DPE). 2. Steam and nitrogen use are okay.
d. Materials of construction	Adequacy of materials of construction specified for the full scale design need to be checked against the test results. Hastelloy C276 (particularly the shell) may not be acceptable for 1500 °F required for induction heating.	<ol style="list-style-type: none"> 1. Upgrade materials and costs. 2. Replace induction heating with resistance heating and eliminate the shell entirely. 	No action required.
e. CatOx hydrocarbon removal performance	The CatOx did not demonstrate high efficiency hydrocarbon removal in EDS I testing and appeared to add to D/Fs.	The results of the EDS I test have indicated that the CatOx units lost efficiency due to fouling with the fine particulates. Increased particulate removal (issue 9(b)) should increase the CatOx performance. If particulates are shown to still be a problem after the completion of EDS I, consideration should be given to how to regularly test the efficiency of the CatOx units and to installing parallel units so one can be taken offline for maintenance without shutting down the process.	No action required.

Table 5-3: Issues from the Design Assessment (continued)

Issue Area	Issue Description	Options for Modification or Adjustment	Resolution
f. Defoamer impact on ICB™	The fate and effect of the defoamer in the ICB™ has not been tested or evaluated.	1. Switch to biodegradable defoamer. 2. Ensure defoamer is nontoxic. 3. Reduce the amount of defoamer required through reduction in particulate carryover.	A biodegradable defoamer (or at least one that is nontoxic to the micro-organisms) is to be used. (Note - The amount of defoamer used is very small.)
g. Capacity/Availability	The CST capacity is sufficiently low for wood dunnage that it requires an extended schedule to complete operations at significant operating cost. Testing problems precluded achieving the assumed reliability/availability for the full scale design. Testing shows ~50% vs. 80% assumed for the full scale system. Most of the problems relate to feed system clogging and downstream particulate control issues.	1. Increase the CST capacity. 2. Properly size feed system. 3. Double the size of the particulate control system. 4. Extend the schedule. See Item 15.	Two CST units will be included at 125% of current capacity each, or each at 75% of required capacity. This will be accomplished by increasing the feed and gas handling systems only since the main CST is believed to be capable of handling this rate. This will require more space in the MDB and increased electrical loads.
10. Munition Reconfiguration	Subsequent to submittal of the final EDS design package, the decision was made that all munitions would be reconfigured by the Depot prior to operations. This impacts numerous design issues and costs, including: <ul style="list-style-type: none"> • wood dunnage to be treated; • need to treat fiber tubes; • PHA issues relating to the PRR; • cost of the MDB; and • operating labor and material req'ts. 	The impacts of this decision cascade through the PHA, design, cost, and schedule assessments. Impacts and options are discussed relative to each issue.	See Items 1; 7(b), 8(b), 11, 15, and 17.
11. Propellant Handling & Processing			
a. Storage safety	Are provisions for handling and storage of propellant adequate from a safety (PHA) standpoint and are the provisions consistent with Army standards?	Subsequent to submittal of the final EDS design package, the decision was made that all munitions would be reconfigured by the Depot prior to operations.	No action required.
b. Storage capacity	Is there adequate storage capacity considering that only one MSB has been provided and it may be inadequate for agent thaw in the winter months?	Subsequent to submittal of the final EDS design package, the decision was made that all munitions would be reconfigured by the Depot prior to operations.	No action required.
c. Propellant loads	GA and Parsons have different propellant loads for 4.2-in mortars (GA at 0.43 lbs vs Parsons at 0.62).	Subsequent to submittal of the final EDS design package, the decision was made that all munitions would be reconfigured by the Depot prior to operations.	No action required.
12. Leakers	No details have been provided as to how leakers are to be handled, stored, and processed.	Assume Baseline approach is adequate for WHEAT.	No action required.

Table 5-3: Issues from the Design Assessment (continued)

Issue Area	Issue Description	Options for Modification or Adjustment	Resolution
13. Mustard Thaw	There may not be adequate provisions for thawing mustard during winter months. There is no analysis of the requirements nor any discussion of the capability of the Munitions Storage Building (MSB) to accomplish this. Current single MSB provides only 24 hours holdup vs. 72 hours reported for adequate thaw.	1. Add (additional) heating to the MSB. 2. Add a dedicated mustard thaw area. 3. Increase the number and capacity of MSBs.	Use three 33% MSBs to allow three days storage for thaw during winter months.
14. Agent Validation	No validation program has been submitted or specific provisions incorporated in the design.	This issue must be deferred to detailed engineering/design in concert with later treaty considerations.	No action required.
15. Dunnage Processing			
a. Wood processing particulate control	The full scale system does not address the need for better particulate control.	1. (Partially) enclose the system. 2. Add proper ventilation.	Design adjustments were made to (Partially) enclose the system and add proper ventilation.
b. Discrepancy in wood quantities	There is a 50% difference in the design basis for wood destruction requirements between WHEAT and GATS.	Resolve discrepancy and make appropriate adjustments in the schedule and/or equipment requirements, as required.	The wood rates utilized by GA are correct. However, the recent decision regarding reconfiguration has obviated processing of boxes and 105mm projectile tubes. The WHEAT wood quantity was increased from 2.8 lb/rnd to 3.25 lb/rnd
c. Requirement for processing uncontaminated wood	There may be no need to process uncontaminated wood pallets and boxes especially since: 1) the Baseline does not process them; and 2) pallets may be required for transporting 5X munition bodies.	Resolve need to process uncontaminated wood and make appropriate adjustments in the schedule and/or equipment requirements, as required.	The current assumption is to process all pallets. Due to reconfiguration (see 10), boxes are not processed. No extension of the schedule is required.
d. Discrepancy in DPE quantities	There is a five-fold difference assumed by GA and Parsons regarding the amount of DPE required to be processed -- 0.7 lbs/round by GA and 0.11 by Parsons.	If the decision cannot be resolved based upon design instructions, select an appropriate amount based upon TOCDF operations and evaluate the impacts on the costs and schedules of two technologies.	Based upon the experience at TOCDF, the Parsons figures were used.

Table 5-3: Issues from the Design Assessment (continued)

Issue Area	Issue Description	Options for Modification or Adjustment	Resolution
16. Water balance provisions	There are inconsistencies in the water balances vs. operating assumptions (e.g., use of dewatering equipment) and balances do not appear to be complete (missing some evaporative streams).	<ol style="list-style-type: none"> 1. Increase BRS capacity. 2. Add additional buffer capacity. 3. Check to see if makeup water properly addressed in O&M costs. 	Add costs for two 75% equivalent BRS trains. This should accommodate unknowns in water balance.
17. Effluents and Emissions	The Emissions and Effluents List provided by Parsons/Honeywell is basically a material balance level document that lacks details in characterizations of most streams. It also is incomplete in identifying all point source and potential fugitive emissions and effluents.	No cost or schedule impacts have been identified except that permit delays could be encountered if incomplete data are submitted.	Add the new vents to the Process Effluents list. Alert ACWA that the supplementary characterization data should be provided as soon as possible. Identify and characterize non-process effluents. Quantify major non-process wastes for disposal cost estimates. See Issue 18.
18. Treatment of Non-process Wastes	GA and Parsons have made different assumptions regarding treatment of non-process wastes: waste oils and lubricants; hydraulic fluids; misc. metal wastes; misc. trash. GA assumes treatment and Parsons assumes disposition during Closure.	<ol style="list-style-type: none"> 1. Leave as is and add costs for waste disposition for Parsons. 2. Assume WHEAT must process these wastes and add cost and schedule as required. 3. Remove treatment of these wastes from GATS and adjust schedule and costs accordingly. 	Leave as is and add costs for waste disposition to WHEAT.
19. General Materials of Construction	Materials of construction overall appear to be relatively immature and not well thought out in some areas. There are numerous inconsistencies and questionable selections. Impact on costs is not determined.	Add a contingency (allowance) for materials upgrade during detailed engineering/design	Add a contingency (allowance) for materials upgrade during detailed engineering/design.
20. I&C Design	The I&C systems may be overly complicated relative to requirements. Also, what appears to be a "one-of-a-kind" master system is specified not yet proven in commercial operations.	Evaluate in concert with Cost Assessment.	An overall contingency of 20% has been added to include requirements for the control room itself, communications systems, and process I&C systems.

Table 5-3: Issues from the Design Assessment (continued)

Issue Area	Issue Description	Options for Modification or Adjustment	Resolution
21. Lab Provisions			
a. Design adequacy	Need to verify that there are adequate provisions for accommodating required analytical work for air (HVAC & emissions), ICB™, and MDB operations and that these provisions are reflected in the capital costs.	<ol style="list-style-type: none"> 1. Increase existing capital costs with a "factored" allowance. 2. Add new capital costs for additional lab space. 3. Add capital cost for new equipment. 	Add cost for properly outfitting the MLA and NMR in the MDB using GCMSs and appropriate support equipment. Cost for new bio lab was added.
b. Operating costs	Need to verify that there are adequate provisions for handling required analytical work for air (HVAC & emissions), ICB™ and MDB operations and that these provisions are reflected in the O&M costs.	<ol style="list-style-type: none"> 1. Increase staffing requirements for tech support if required. 2. Add cost for other operating components as required. 	Staffing appears adequate. Add cost for lab service agreements.

Source: Arthur D. Little, Inc.

It is important to note before the discussion that the operating costs of the WHEAT facility are “high” compared to the incremental capital costs of most potential adjustments (see Section 8.0, Cost Assessment) to improve reliability and throughput. The typical weekly operating costs, mainly for labor, make the trade-off between increased capital costs versus reduced operating costs, easy to determine in favor of capital cost modifications.

5.3.1 Design Issues and Resolutions

5.3.1.1 Throughput Assessment (Issue 1). The Throughput Assessment for the Parsons/Honeywell WHEAT process, as well as General Atomics and Baseline (see Appendix A), is not intended to be a detailed availability/reliability analysis of the PUCDF based on a Reliability/Availability/ Maintainability (RAM) study. Rather, this assessment is intended to put all three technologies on the same basis to allow a comparison to be conducted. As such, the results of this assessment cannot be taken and compared directly to another Technology unless the basis for the new technology is modified to incorporate the assumptions in this assessment. The non-technology specific assumptions for this assessment are presented in Table 5-4. The overall approach for the Throughput Assessment is presented in Figure 5-2.

**Table 5-4: General Throughput Assessment Assumptions
(External Causes of Downtime)**

Description	Assumption
Holiday Shutdowns	<ul style="list-style-type: none"> Christmas to New Years Day – 9 days Thanksgiving Weekend – 5 days
Unplanned and Scheduled maintenance downtime	<ul style="list-style-type: none"> 70 days/yr
Externally-Caused Shutdowns	<ul style="list-style-type: none"> Power outages, requiring orderly shutdown – 3 times/yr x 16 hrs/occurrence = 2 days/yr Weather related – 4 days/yr Munition delivery problems – 6 days/yr Other – 2 days/yr
Operating Mode	<ul style="list-style-type: none"> 7 days/wk
Maximum Annual Availability	<ul style="list-style-type: none"> 73.2%

Source: Arthur D. Little, Inc.

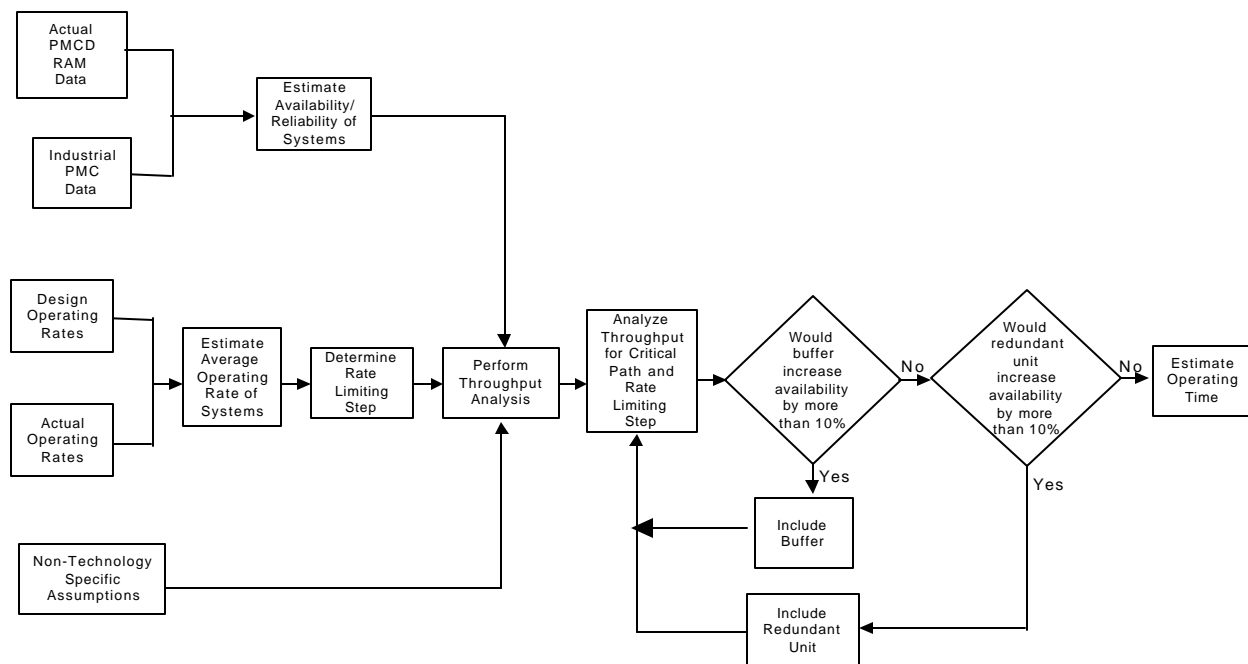
The first step in the Throughput Assessment was to review the Parsons/Honeywell PUCDF design and determine the major unit operations in WHEAT. The result of that review is presented in Process Flow Diagram in Figure 4-1 and discussed in Section 4.0, WHEAT Technology and Testing Description. After agreement was reached on each of the unit operations, the units were reviewed to determine which were coupled and which were uncoupled based on a buffer between them. For those units that were separated by the existence of a buffer, an analysis was performed to determine whether the normal operation would have the buffer filled or empty and how long it would take the upstream unit to fill the buffer or the downstream unit to empty the buffer. This information formed the basis for tailoring the Throughput Model to WHEAT.

Using PMCD operating data (see Appendix A), PMACWA demonstration test data, and/or Industrial data, average operating rates (the average rate when operating) and availabilities for

each of the unit operations were estimated (Table 5-5). The estimated operating rates and availabilities were then entered into the WHEAT Throughput Model. The results of the Throughput Model were, in turn, reviewed to determine what system was the limiting step, what the critical path through the facility was, and what systems caused a major reduction in availability. For those systems with low availability, three types of adjustments were considered:

1. Increasing an existing buffer or adding a new buffer capacity to decouple operating equipment/systems from the rest of the facility
2. Adding a new piece of equipment or system to increase availability and/or operating rate
3. Increasing the size/capacity of an existing piece of equipment or system

Figure 5-2: Throughput Assessment Approach



Source: Arthur D. Little, Inc.

In evaluating WHEAT, the critical path through the facility was clearly through the reverse assembly process, the RMPT, MPT PAS, MPT condensate storage, the ICBs™, and the BRS. This critical path is very similar to Baseline; however, unlike Baseline, the WHEAT design had no buffer between the PMD and the Multipurpose Demilitarization Machines (MDMs) and had only two MDMs instead of three. Both of these differences significantly impacted the availability of the facility. To reduce the coupling between the PMD and MDM an eight hour buffer was included. The design of the buffer was assumed to be similar to the Baseline buffer. A third MDM (including an RWM) was added to WHEAT to allow the MDM to work off buffer and increase the availability of the reverse assembly process.

Table 5-5: Estimated Operating Data per Unit Operation

Unit Operation	PMACWA WHEAT Model			Comments
	Avg Operating Rate ¹ (Mun/hr)	Peak Operating Rate (Mun/hr)	Availability	
PMD	30	75	70%	The WHEAT PMD is very similar to the Baseline PMD and therefore has the same Avg Operating Rate and Availability. Buffer capacity similar to Baseline was added between the WHEAT PMDs and MDMs to decouple these units.
MDM	25	50	68%	The WHEAT MDM is expected to be able to process at the same rate and be as reliable as the Baseline MDM. Both MDMs (WHEAT and Baseline) would be expected to be based on the EDS I PWS tests and JACADS operating data. An additional MDM was added to the WHEAT design to increase capacity and availability.
RWM	25	50	90%	The RWM has not been tested and the operating rates are engineering estimates. An additional RWM was added to WHEAT. The results of the current EDS I tests will be used to adjust these estimates.
RMPT	60	120 – 155mm 240 – 4.2in/105mm	88%	The RMPT or a similar unit was assumed to be as available as the Baseline MPF. As with the Baseline MPF an additional RMPT was added to increase the availability.
BMPT	60	60 – 155mm 120 – 4.2in/105mm	90%	The BMPT was assumed to have a high availability based on the simplicity of the equipment.
MPT PAS	60	60 – 155mm 120 – 4.2in/105mm	95%	The MPT PAS was assumed to have a high availability based on the simplicity of the equipment. The availability was estimated based on industrial information and then corrected for being located in an agent environment.
Agent Hydrolysis	NA	570 lb agent/hr	95%	The Agent Hydrolysis unit was assumed to have a high availability based on the simplicity of the equipment. The availability was estimated based on industrial information and then corrected for being located in an agent area. The reactors were increased 33% to allow for a reverse assembly higher peak operating rate. Additional agent and agent concentrate storage was added to further decouple agent hydrolysis from reverse assembly.
Energetic Hydrolysis	NA	75 lb tetrytol/hr	99%	The Energetic Hydrolysis unit was assumed to have a high availability based on the simplicity of the equipment and the large amount of excess capacity in the system. The availability was estimated based on industrial information and then corrected for being located in an agent environment.
ICB TM	NA	16,000 lb hydrolysate/hr	98%	The ICBs TM were assumed to have a high availability based on the simplicity of the equipment.
BRS	NA	72,000 lb brine/hr	99%	The availability is based on other similar systems. The availability used in the model was increased to 99% due to the addition of a second BRS and significant buffer capacity.
Mechanical Availability ²	NA	NA	44%	The operating rate of 60 munitions/hr requires all three MDMs to be operational.

NA Not Applicable

¹ The Operating Rates for PMD and MDM are per machine² The Mechanical Availability was calculated using the Throughput Model

Source: Arthur D. Little, Inc.

Once the third MDM was added, the Agent Hydrolysis unit was increased by 33% to match Parsons/Honeywell's Optional Throughput Scenario, and an additional 500 gallon Agent Storage Tank and an additional 500 gallon Agent Concentrate Storage Tank were added with the corresponding pumps and piping. These adjustments kept agent hydrolysis from being a bottleneck within the facility.

The Parsons/Honeywell Engineering Package design had only one RMPT with limited buffer capacity between it and the MDM. Because the availability of the RMPT was critical to the overall availability of the facility, the Parsons/Honeywell Engineering Package design was adjusted to include a second RMPT of the same size.

A second BRS was added to the facility to increase the availability of the BRS and to increase the ability of the BRS to work off buffers if they built. While the brine buffers do not impact the ability of the facility to destroy munitions they can cause the facility to continue operation significantly beyond the completion of the munitions operating campaigns.

After the adjustments were made to the Throughput Model, the model was rerun and a mechanical availability, total availability, and average campaign throughput for each munition type was calculated (see Table 5-6). The calculated mechanical availability was 44%. The mechanical availability represents the availability of the equipment on the critical path through the plant without taking into account external causes of downtime (e.g., administrative, programmatic, general maintenance). The 44% is similar to the facility availability observed for the one month 105mm Projectile Full Rate Operational Verification Testing (OVT) JACADS Campaign and approximately 40% greater than facility availability observed for the 4.2-inch Mortar JACADS Campaign. The calculated total availability was 33%. The total availability represents the availability for the total plant including mechanical and external sources of downtime. The assumptions used to calculate the external sources of downtime are presented in Table 5-4.

Table 5-6: WHEAT Throughput Model Results

Munition Type	Number of Munitions	Avg. Campaign Throughput ²	Operating Time ³
4.2-inch mortar	97,106	19.5 munitions/hr	29.6 weeks
155-mm projectile	215,244 ¹	19.5 munitions/hr	65.7 weeks
105-mm projectile	383,418	19.5 munitions/hr	117 weeks

1. 84,310 155-mm projectiles are assumed to be destroyed during a one year startup and pilot test period

2. Based on 2 PMDs and 3 MDMs in operation

3. Operating time does not include time for changeovers between munition type or for rejected munitions

Source: Arthur D. Little, Inc.

Once the total availability was calculated, the average campaign throughput rate was calculated by multiplying the estimated average operating rate, of 60 munitions/hour, by the total availability. The resulting average throughput rate for WHEAT was 19.5 munitions/hour. This rate is approximately 25 to 40% higher than the average throughput rates observed at JACADS for the entire 4.2-inch mortar campaign (11.6 mortars/hr) and the entire 105mm projectiles OVT (14.9 projectiles/hr, assumes maintenance of 15 hours/week during the off-shift). While the WHEAT average throughput rate is greater than the complete 4.2-inch mortar campaign or the

105-mm projectile OVT, it is lower than the best sustained short-term rates observed during either campaign: 29 mortars/hr for 35 days during the 4.2-inch mortar campaign, and 25 projectiles/hr for 26 days during the Full Rate OVT. The throughput rates observed for JACADS are relevant to the WHEAT process because of the similarity in the critical path through both facilities. The improvements to the similar processes by Parsons/Honeywell and the Design Assessment team provide confidence that the calculated average throughput can be achieved. The calculated average throughput rate was used as the basis for the adjusted WHEAT schedule (see Section 7.0) and the operating schedule for each munition is presented in Table 5-6.

In order to further evaluate the reasonableness of the Throughput Assessment, a cursory sensitivity analysis was performed to determine how the operating schedule would be impacted based on the range of average throughput rates observed at JACADS. Table 5-7 presents the sensitivity of the operating campaign schedules to a potential high and low average campaign throughput. The analysis shows that as much as 1.5 years could be reduced off the operations schedule if the WHEAT process operated at the best sustained rates observed at JACADS and as much as 1.25 years could be added to the operations schedule if the WHEAT process operated at the lowest sustained rate.

Table 5-7: Throughput Assessment Sensitivity Analysis

Munitions	High Throughput Rate		Moderate Throughput Rate		Low Throughput Rate	
	Rate (mun/hr)	Operating Schedule (weeks)	Rate (mun/hr)	Operating Schedule (weeks)	Rate (mun/hr)	Operating Schedule (weeks)
105-mm projectiles	30	76	19.5	117	15	152
155-mm projectiles	30	43	19.5	66	15	86
4.2-inch mortars	30	19	19.5	30	15	38
Total Operations	---	138	---	213	---	276

5.3.1.2 PMD, MDM, & RWM (Issue 2). During operations at JACADS with mustard projectiles and mortars, a number of difficulties arose with the Baseline reverse assembly that caused significant limitations in the facilities ability to destroy the munitions. There were several difficulties with the Projectile/Mortar Disassembly Machine (PMD) and its ability to download the energetics. Most of these problems were corrected during the campaign and the final PMCD analysis on the PMD is that it is capable of operating effectively with all three mustard munitions present in the PUCDF stockpile. The WHEAT PMDs are based on the Baseline PMD with the only modification being the addition of a Burster Washout Machine to slurry the tetrytol in place of the Baseline Burster Shear Machine.

The operational problems with the MDMs during the mustard munitions campaigns were more difficult to resolve. The MDMs had significant problems with the mustard “champagne” effect, significant mustard heels (between 60 and 80%), and difficulty in pulling the 4.2-inch burster wells. During the operations at JACADS, PMCD was not able to modify the system to improve the MDMs operations significantly. Parsons/Honeywell has taken the lessons learned at JACADS and redesigned the MDM to enhance the operability of the agent accessing process.

The January 2001 Parsons/Honeywell Engineering Package is based on the use of a modified MDM followed by a Projectile Washout Machine. The MDM is modified to contain the

champagne effect and invert the munition after the burster well is pulled to drain the agent. The RWM uses high pressure water to washout the agent heel. During the design of the Projectile Washout testing for the EDS I Program, Parsons/Honeywell modified their approach to eliminate the burster well pull station for the 4.2-inch mortars and replace it with a system to cut off the mortar base plate and incorporate the RWM as a station in the modified MDM.

No matter how the accessing, draining, and washout steps are configured there is no data currently available to demonstrate that the approach will work or what the outputs of the system will be. Therefore, the WHEAT MDM and RWM were considered to represent an area of high technical risk within WHEAT. To account for the high technical risk, the design was adjusted in three ways:

1. The coupling of PMD and MDM operations was reduced by adding buffer storage capacity after the PMD. This system included a conveyance system consistent with Baseline operations. The buffer was assumed to hold approximately 8 hours of munitions.
2. A third MDM and RWM were added to the WHEAT process. The additional units increase the overall availability of the MDM/RWM system and reduce the potential risk associated with the system.
3. The Pilot Test schedule was increased to one year to allow for the time needed to correct interface problems between the new pieces of equipment.

An additional concern with the RWM is how much agent heel will remain in the munition after the washout step is complete. Parsons/Honeywell state the quantity of agent heel will be 2%; however, there is no justification for this assumption or an analysis to determine how sensitive the RMPT is to the quantity of agent remaining in the munition. During the Design Assessment, a review of the MPT Pollution Abatement System (PAS) was conducted to determine whether agent heels of greater than 2% posed a problem for the MPT PAS. The review indicated that the PAS should not be impacted by heels of up to 50%. Above this level there would be a need to increase the size of the downstream PAS equipment. Up to the level of 50% there would be a higher gas loading on the quench and organic loading on the CatOx unit but both units should have sufficient capacity to handle the increases. The quantity of condensate would also increase; however, the Agent Hydrolysis System should have sufficient capacity to handle the additional condensate if it does not clear for release to the Hydrolysate Storage Area.

In conclusion, the MDM/RWM are considered to be fundamental to the success of WHEAT. This area will drive the schedule and determine the overall operability of the plant. The Design Assessment has reduced the technical risk by the adjustments made, but a complete assessment of this area of the design can not be completed until after the EDS testing is complete. The Projectile Washout System (PWS) EDS I testing is planned to be performed at CAMDS at Deseret Chemical Depot, Utah with HD and HT 4.2-inch mortars. CAMDS will download the energetic components from the mortars using their PMD, and the PWS will access the agent cavity, drain the agent, and washout the agent heels. The drained agent and washed out agent will then be hydrolyzed. The washed out mortar will be 5X decontaminated in a demonstration-scale RMPT.

5.3.1.3 Rotary Metal Parts Treater (Issue 3). After the munition bodies are washed out, the bodies are decontaminated in the RMPT. The RMPT performs the same function as the Baseline Metal Parts Furnace (MPF). In the RMPT the munition bodies are radiantly heated by induction heaters on the shell of the RMPT and steam is used to sweep any organics volatilized out of the chamber to the downstream MPT Pollution Abatement System (PAS). Unlike the Baseline MPF which feeds the munitions in batches on trays, the RMPT feeds one munition at a time to the MPT chamber. The advantage of the RMPT feed system is that it minimizes the quantity of agent fed to the chamber at any time; however, it does significantly complicate the unit. During the design assessment four key issues were identified:

1. Adequacy of the RMPT materials of construction
2. Mechanical performance of the unit
3. Horizontal loading of the munitions into the unit
4. Availability of the unit

Materials of Construction. Materials of construction testing was performed during the EDS CatOx test and during the EDS I CST test. Both of these tests have shown that Hastelloy is an effective material for the environment expected in the RMPT (high temperature, steam, and high chloride). Therefore, the selection of Hastelloy as the material of construction for the RMPT is considered to be adequate.

Mechanical Performance and Horizontal Loading. As mentioned above, the RMPT feeds one horizontal munition at a time as opposed to the Baseline MPF that feeds a batch of munitions in trays. This raised two concerns during the Design Assessment. The first concern was the increased complexity and reduced reliability associated with a large rotating chamber, and second was the loading of the munitions horizontally limiting volatilization of the agent out of the munition because the munitions are tightly packed together. The Design Assessment did not substitute a BMPT design for the RMPT because the RMPT is expected to have a higher cost. However, during the final design attention should be paid to the selection of the concept for handling the munitions in the Metal Parts Treater and a system based on the BMPT should be considered. This is especially true if the EDS I testing demonstrates the Projectile Washout System to be effective for removing agent heels because the advantage of feeding the munitions individually is lost. Another advantage of a Batch MPT for the munition bodies is that the current small BMPT could be eliminated and the feed could go to the larger BMPT. Also, Baseline has considered treating dunnage through the MPF and two large BMPTs would allow this flexibility if a problem arises with the Continuous Steam Treater (CST).

Unit Availability. The final key issue was the unrealistically high availability Parsons/Honeywell proposed for the RMPT. The RMPT is on the availability critical path through the WHEAT facility. Because the unit is on the critical path and there is only one unit in the WHEAT design, attention was paid to whether a second unit would significantly increase the availability of the facility (see Section 5.3.1.1, Throughput Assessment). The Throughput Assessment indicated that a second RMPT would increase the availability of the facility and reduce the operations schedule; therefore, the design was adjusted to include a second RMPT. This is the same adjustment that was made to Baseline (see Appendix A).

5.3.1.4 Agent Neutralization (Issue 5). Several issues concerning the agent neutralization area of the process were identified during the Design Assessment. These issues include:

1. Agent hydrolyzer sizing
2. Agent storage capacity
3. pH adjustment
4. Agent hydrolyzer release criterion

Agent Hydrolyzer Sizing. The Parsons/Honeywell Design Basis presents an option for increasing the size of each Agent Hydrolysis Reactor by 33% in order to increase the operating capacity of the Agent Hydrolysis Area. The 33% increase in the reactor size would increase the working volume of the reactor from 1,525 to 2,030 gallons and increase the quantity of HD destroyed per batch from approximately 430 to 570 lbs. During the Throughput Assessment the number of MDM/RWMs was increased from two to three units. This increase in the number of units increased the average operating rate for the Agent Accessing Area from 50 munitions/hr to 75 munitions/hr. At that rate, the Agent Hydrolysis Area became the bottleneck for the facility when 155mm projectiles were being processed. Therefore, during the Design Assessment, the size of the Agent Hydrolysis Reactors was increased by 33%. This adjustment, along with the increase in the buffer capacity for the drained agent and agent concentrate (see discussion below), allows the MDM/RWMs to operate at 75 munitions/hr (155mm projectiles) for 48 hours before the Agent Hydrolysis Area becomes a bottleneck.

Agent Storage Capacity. The Parsons design has one 500-gallon Agent Storage Tank, one 500-gallon Agent Concentrate Tank, one 1,020-gallon Agent Surge Tank (which serves as an overflow tank for the Agent Storage Tank or the Agent Concentrate Tank), and a pair of agent and agent concentrate feed pumps. This system serves as the buffer and feed system between the RWM and the six agent hydrolyzers located in three toxic cubicles (two hydrolyzers per toxic cubicle). Depending on the quantity of agent heel in the munition, the agent storage area has a buffer capacity of 10 to 20 hours if the Agent Surge Tank is not used. The results of the Throughput Assessment indicated that buffer capacity could limit operations if the three MDM/RWM operated at their average operating rate (25 mun/hr/machine) for more than a day during the 155mm projectile campaign and more than 2 days for the 4.2-inch mortar campaign. In addition, the WHEAT Toxic Storage Area was compared to the ABCDF agent storage and feed system, which consists of an Agent Storage Tank, Agent Surge Tank, and pair of feed pumps in each toxic cubicle. Based on the Aberdeen Chemical Agent Disposal Facility (ABCDF) design and the need to limit the coupling between the Agent Hydrolysis and reverse assembly, the WHEAT design was adjusted to include an additional 500-gallon Agent Storage Tank, 500-gallon Agent Concentrate Tank, and 1,020-gallon Agent Surge Tank and associated pumps, piping, and instrumentation. During the final design, consideration needs to be given to increasing the volume of the Agent and Agent Concentrate Tanks to further limit the coupling between the Reverse Assembly and the Agent Hydrolysis Areas.

Agent Neutralization pH Adjustment Step. The WHEAT HD hydrolysis batch cycle is the same as that developed for the ABCDF Acquisition Design Package (ADP, April 1996). It is comprised of the following steps:

- Hot water fill
- Heat water
- Agent feed
- Reaction
- Sample collection and analysis (HD)
- NaOH feed (raise the hydrolysate pH from <1 to between 10.5 and 12)
- Empty

In response to recent Project Manager for Alternative Technologies and Approaches (PMATA) testing results and delisting efforts, a new batch cycle has been developed for ABCDF. The ABCDF batch cycle has been modified to adjust pH prior to sample collection and analysis rather than after. In addition, the hydrolysate pH will be adjusted to neutral rather than between 10.5 and 12 within the reactor. The reasons for these modifications are as follows:

1. The low pH (<1) of the hydrolysate prior to pH adjustment, the presence of thiodiglycol in the hydrolysate, and the high temperatures in the analytical instrument (GCMS) combine to form HD when the sample extract is injected into the instrument. This has the effect of false positive HD results. Adjusting the hydrolysate pH prior to sample collection will preclude the formation of HD in the instrument and avoid the accompanying false positive results.
2. The titration curve for pH adjustment of HD hydrolysate is very steep, with the knee of the curve around 11. This makes it difficult to adjust the pH to between 10.5 and 12 without overshooting the target. Overshooting the target has two drawbacks: additional chemical feed equipment required within the toxic cubicles to bring the pH back down, and additional time to finish the batch. The ABCDF modification avoids these drawbacks by adjusting the hydrolysate pH to neutral with any additional pH adjustments made downstream.
3. In Maryland, HD is a listed hazardous waste, carrying both toxicity (HD) and corrosivity (pH) codes. In order to be delisted at the neutralization reactor, the hydrolysate must be non-detect for HD with a method detection limit (MDL) ≤ 20 ppb and the pH cannot be less than 2.5 or greater than 12. If the target pH remains between 10.5 and 12, all of the problems described in the previous bullet are realized. Similarly, modifying the target pH to neutral avoids these problems.

The modified ABCDF agent neutralization batch cycle is not reflected in the Parsons Design Package. This modification does not impact the batch cycle time or equipment requirements and therefore, should not impact cost and schedule. This change and others resulting from ongoing neutralization/biotreatment testing by ABCDF should however, be addressed in future Design Packages.

Agent Hydrolyzer Release Criterion. The Parsons Design Basis states that the agent concentration must be less than 330 ppb in order to release a batch of agent hydrolysate from the agent hydrolyzers. The ABCDF release criterion is non-detect with a method detection limit (MDL) ≤ 20 ppb. No action is required for this issue because the Parsons agent hydrolyzer design is based on the ABCDF neutralization reactor design and should achieve the same level of

treatment. In addition, the design is based on the PMACWA testing that was conducted at ECBC for HD hydrolysis, and the results of this testing demonstrated that a final HD concentration of <20 ppb was consistently achievable. This error should be corrected in future design documents.

5.3.1.5 Biotreatment (Issue 7). Several issues were identified during the Design Assessment concerning the Immobilized Cell Bioreactors (ICBsTM). These issues include:

1. Propellant ICBTM testing
2. Agent heel quantities
3. HT hydrolysate biotreatment
4. Dioxins and furans

Propellant ICBTM Testing. At the outset of the Design Assessment, testing of the treatment of M1 and M8 propellant hydrolysates in ICBsTM was just underway. There was concern that the lack of test data may present a risk, albeit minor, to cost and schedule. These concerns have been minimized for several reasons.

First, early test results indicate that the propellant hydrolysates, which are being tested in separate ICBsTM, are at least partially biodegradable at the following test loading conditions:

- M1 and M8 hydrolyzed at 6.7 wt%
- 200 mL of propellant hydrolysate per 1000 mL of ICBTM feed
- 5-day hydraulic residence time in the ICBsTM

Under these conditions, organic removal efficiencies are between 30% and 40% in the M1 hydrolysate ICBTM and between 60% and 70% in the M8 hydrolysate ICBTM. At reduced propellant loadings, which the full-scale ICB sizing could easily accommodate, biodegradability is likely to improve. Second, treatment of the propellants with the agent and energetics hydrolysates, rather than after as proposed by Parsons, appears to be a possibility from both a schedule and technical point of view. Finally, plans to have the remaining boxed munitions reconfigured by others prior to pilot testing may eliminate the propellants as a waste that will be treated by PUCDF.

Agent Heel Quantities. Agent contained within the munitions is in two forms: liquid agent that is drained from the munitions in the MDM and semi-solid/solid agent, called heel, that is washed out of the munitions in the RWM. Two issues are of concern here. First, the ratio of heel to drained agent in the munitions has not been determined for the Pueblo stockpile. Second, biotreatment testing of combined drained agent and heel hydrolysate from munitions has not been conducted. These issues are raised because the analysis of the contents of HD ton containers at APG shows that agent heel contains a lower fraction of HD than the drained agent. The heel hydrolysate, therefore, contains a higher fraction of low and non-biodegradable products (i.e., less thiodiglycol), which may impact the performance of the ICBsTM.

Laboratory feasibility testing conducted by PMATA on APG ton container heel and drained agent hydrolysates demonstrated the correlation between heel quantity and organic removal

efficiency across a biotreatment process: in this case, sequencing batch reactors (SBRs). The results of this testing are illustrated in Figure 5-3. Four SBRs were operated with feeds that represented the following ton container heel to total agent wt/wt ratios:

- Zero percent heel, all drained agent hydrolysate (control)
- 13.5 percent heel
- 27 percent heel
- 100 percent heel

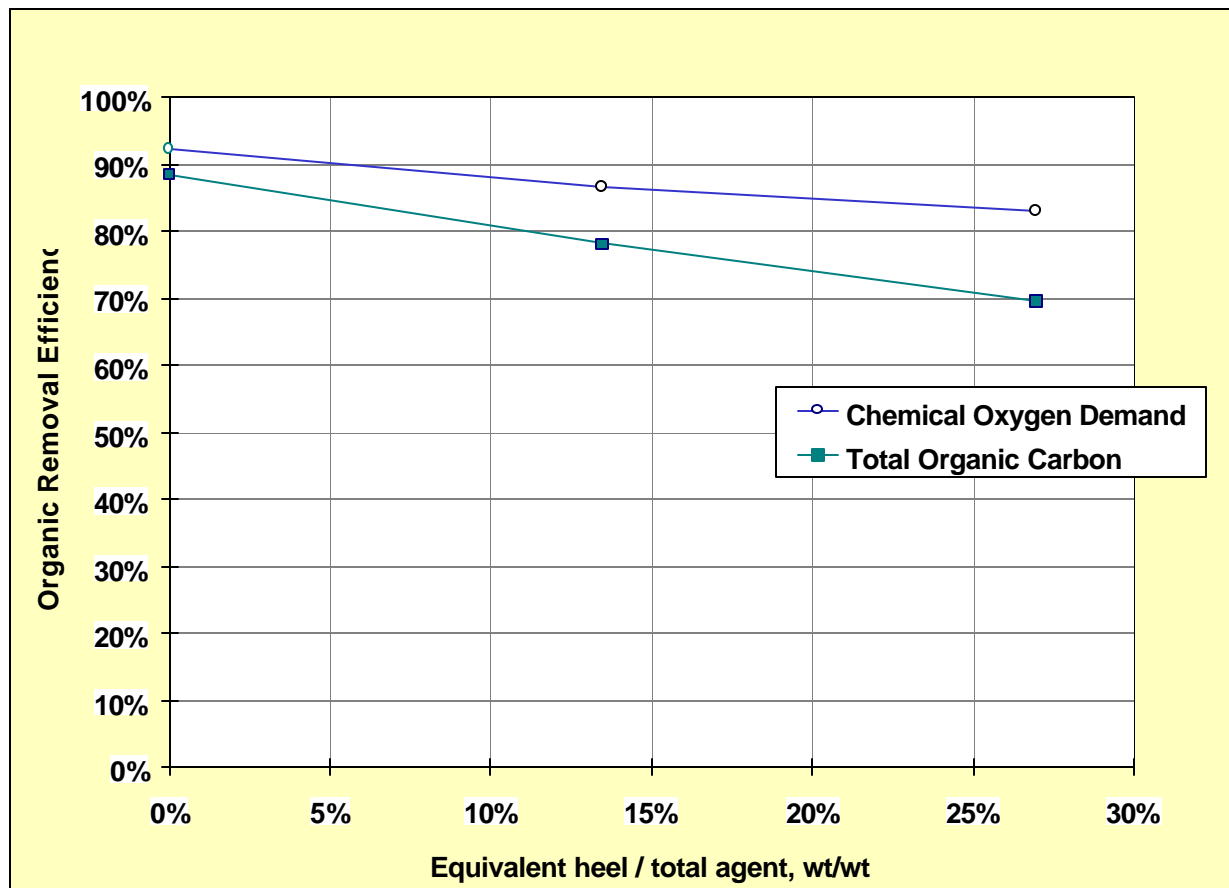
The results of the last test listed above, 100 percent heel, are not shown in Figure 5-2 because stable operating conditions could not be achieved with that feed. The combined results from all four SBRs indicate that at levels somewhere between 27 percent and 100 percent heel, stable biological degradation became unachievable.

Bechtel Aberdeen is currently conducting additional HD neutralization/biotreatment testing for PMATA at Battelle in West Jefferson, Ohio. This testing supports the Preliminary Assessment of Health Impacts (PAHI) of ABCDF effluents and emissions, which is being conducted by the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) on behalf of The U.S. Army Surgeon General. Air emissions from the neutralization and biotreatment processes and the liquid biotreatment effluent will undergo extensive compositional analysis. In addition, mammalian and aquatic toxicological tests will be conducted on the biotreatment effluent. Three feed/operating scenarios are being tested for the PAHI:

- Control: 1.27 wt% thiodiglycol fed to an SBR, no heel
- Best case: High-HD content agent (about 95%), drained agent hydrolysis at 3.8 wt%, hydrolysate diluted to an equivalent agent concentration of 1.27 wt% for SBR feed, heel at 6.4% of total agent, iron floc settled and removed from heel hydrolysate prior to combining with drained agent hydrolysate.
- Worst case: Low-HD content agent (about 85%), drained agent hydrolysis at 8.6 wt%, hydrolysate diluted to equivalent agent concentration of 1.27 wt%, heel at 13.4% of total agent, no settling of heel hydrolysate prior combining with drained agent hydrolysate.

PAHI Test support personnel report that, despite some operational problems, the three SBRs are performing well. [No formal reports are available at this time.] Even the worst-case SBR with 13.4% heel is achieving organic removal efficiencies (as measured by COD) above 85%. These results are consistent with the findings of the earlier ECBC testing. The ECBC and PAHI testing, however, may not bound the heel quantity in the Pueblo munitions.

Figure 5-3: Organic Removal Efficiency in Biotreatment Versus Ton Container Heel/Total Agent



Source: SBR Technologies

The WHEAT design assumes that at least 60 percent of the agent within a given round will be drainable. That leaves a heel quantity of up to 40 percent. In light of the test results illustrated in Figure 5-3, biological treatment of the combined heel and drained agent hydrolysate at Pueblo could be problematic. Without analytical and quantifiable data on the heel material however, the performance of a biological system treating this stream cannot be predicted.

The MDM and RWM EDS test is scheduled for July 2001 (see Issue 5). At that time, a limited (based on only a few data points) determination can be made of the composition and quantity of heel to expect in the Pueblo munitions. If this analysis shows that the quantity of heel is low and/or the organic content of the heel is comprised mostly of HD, then successful biotreatment can probably be achieved. If the heel quantity is high and the organic content is made up mostly of non-HD compounds, then biotreatment could be very difficult. In either case, laboratory scale biotreatment testing is recommended to determine the impact of the heel on organic removal efficiency in biotreatment.

HT Hydrolysate Biotreatment. The EDS I testing conducted by Parsons has not included any testing using HT. This is understandable given the similarities between HD and HT and the small

quantity of HT munitions in the Pueblo stockpile-less than 3 percent. As part of the Design Assessment, results from earlier studies conducted at ECBC on the hydrolysis of HT and biotreatment of HT hydrolysates were reviewed. The objective was to identify dissimilarities that might impact treatment of HT and HT hydrolysate in a process designed primarily for the treatment of HD and HD hydrolysate.

Critical findings/conclusions of the referenced ECBC studies on hydrolysis of HT and biotreatment of HT hydrolysate are as follows:

- NMR results show H at 51.4 mole% and T at 28.2 mole%.
- Water hydrolysis of HT at 3.8 wt% and 90°C proceeded to completion (H and T concentrations below 1 ppm) within about 30 minutes.
- The half-lives (measured down to 1 ppm) under these conditions are 1.4 minutes and 1.6 minutes for H and T, respectively.
- NMR analysis of the HT hydrolysate shows that thiodiglycol and T-OH are the major organic products at 55.7 area% and 27.8 area%, respectively. These results indicate a very high conversion of H to thiodiglycol and T to T-OH.
- At a hydraulic residence time of 10 days in a sequencing batch reactor (same conditions as the ABCDF HD biotreatment system), the organic removal efficiency was about 82 percent.

Together, these findings/conclusions indicate that a neutralization/biotreatment process that has demonstrated satisfactory treatment of HD and HD hydrolysate, as has the WHEAT process, will also perform satisfactorily in the treatment of HT and HT hydrolysate.

Dioxins and Furans. EDS I testing has shown the presence of significant concentrations of dioxins and furans in the CST condensate (see Issue 9). This stream is treated in the ICBs™ with the agent and energetics hydrolysates. The impact on ICB™ operation was questioned during the Design Assessment, but based on a review during the assessment, no impact is expected. The CST condensate makes up a very small portion of the ICB™ feed, less than 1%. Therefore, even when dioxin and furan levels in the CST condensate are at the highest values seen during EDS testing, the levels in the ICB™ feed will be below regulatory limits.

During ICB™ EDS testing, there was one instance of furan detection in the ICB™ feed and effluent. The concentrations were virtually the same indicating pass through. Modifications have been recommended for the BRS to capture any dioxins and furans that pass through the ICB™ to the BRS (see Issue 8).

Other questions arose about the possibility of formation of dioxins and furans in the ICB™ CatOx. Test results indicate, however, that dioxins and furans are not being formed in the ICB™ CatOx.

5.3.1.6 Brine Reduction System (Issue 8). The Parsons/Honeywell Engineering Package utilizes only one Brine Reduction System (BRS) train. Due to the significant problems that the Baseline facilities have had with brine reduction and that the reliability and operability of the WHEAT BRS have not been tested or adequately justified, the BRS was considered to be an area

of high risk for significantly reducing availability or being an overall performance pinch point within the facility. During the Design Assessment three key issues arose:

1. Availability of the BRS
2. Ability to process brine from the biological treatment of the propellant hydrolysate
3. Ability of the BRS to handle dioxins and furans

Availability. In the current design, the ICB™ effluent is pumped either to the biomass dewatering system then to the BRS or directly to the BRS. The dewatering system includes redundant components, each handling 50% of the design load, to “reduce the effect of downtime due to maintenance and repair.” The BRS however, consists of a single train consisting of: one brine concentrator and one evaporator/crystallizer. The Evaporator Feed Tank (090-Tank-101), which provides the majority of ICB™ effluent storage capacity, has an operating capacity of 158,000 gallons. At the design ICB™ effluent rate of 36,300 lb/hr (155mm Steady State/DPE Case), the Evaporator Feed Tank provides less than 1.5 days of buffer. This tank also receives boiler blowdown from utilities, and the evaporator/crystallizer requires biweekly boil-out lasting 16 hours. (During this period it might be possible to process the ICB™ effluent in the brine concentrator and hold the concentrator effluent in the Evaporator/crystallizer Feed Tank [Tank-108] until the evaporator/crystallizer is back on line.) The single BRS train and limited storage buffer present significant risk to throughput and schedule. The resolution for this issue is to adjust the design to include two 75% BRS trains. Replacement of the single, existing 100% train with two, 75% trains will essentially double all BRS vessels, pumps, piping, controls and other appurtenant equipment, albeit at a somewhat smaller capacity. It appears that there is sufficient floor space in the PAB; however, the addition of a second BRS will require expanding the existing penthouse to accommodate the second 80-ft. high unit. There will also be requirements to increase the capacity of existing electrical supply and distribution systems.

Brine from Bio Treatment of the Propellant Hydrolysate. Treatment of propellant ICB™ effluent in a BRS has not been conducted. It cannot be determined whether there are any performance issues related to processing the organics in the BRS since this was not tested. The additional BRS capacity is presumed to resolve this issue. Having 2 x 100% equivalent BRS trains is expected to provide more than adequate capacity to treat the propellant ICB™ effluent. If munitions are reconfigured prior to demilitarization operations and the propellant disposed of by the Depot, this issue becomes moot.

Dioxins and Furans. EDS I testing has shown that significant amounts of dioxins and furans are being generated within the CST. These compounds are present in the CST vent stream and condensate as a result of the treatment of a DPE and wood mixture and the operating temperatures of the CST. The CST vent is treated by CatOx units to destroy any remaining organic materials; however, during the EDS testing the CatOx units have not been effective in removing dioxins and furans. The CST condensate will be treated with the agent and energetics hydrolysates in the ICBs™ followed by the BRS. The dioxins and furans are expected to pass through the ICBs™ and to be present in either the ICB™ gas or liquid effluent streams. The ICB™ EDS I testing with the CST condensates did not indicate that the dioxins and furans were present in the ICB™ gas effluent. This was the expected result due to the non-volatile nature of the compounds. Therefore, the dioxins and furans are expected to be present in the brines treated

in the BRS. The majority of the dioxins and furans treated in the BRS are expected to remain with the salts and be disposed of off site. However, due to the high temperature of the BRS, they may be present in the BRS at some concentration. In the Parsons/Honeywell Engineering Package, the BRS vent is connected to the ICB™ off gas and treated in the ICB™ CatOx units. Because of the poor results with the CST CatOx removing dioxins and furans during the EDS I tests, the design was adjusted to include a dedicated carbon filter unit on the BRS vent followed by discharging the treated gas to the atmosphere. In addition, ongoing CST EDS I testing is examining ways to reduce the formation of dioxins and furans.

5.3.1.7 Continuous Steam Treater (Issue 9). During the Design Assessment, the CST was considered to have significant issues that could impact its ability to operate as proposed during full-scale operations. In addition, the limited capacity of the CST caused a significant increase in the Parsons/Honeywell operating schedule. Specifically, seven key issues were identified with the CST:

1. Formation of dioxins and furans in the CST
2. Impact of fine particulate generated in the CST on downstream equipment
3. CST design in the Engineering Package does not incorporate the EDS I test results
4. CST materials of construction
5. Organic removal performance of the CatOx units during EDS I testing
6. Impact of the quench tower defoamer on the ICBs™
7. Availability and capacity of the CST

Dioxin and Furan Formation. Substantial amounts of dioxins and furans were generated within the CST and CatOx unit operations during the EDS I testing. Unfortunately, conditions within the CST favor the formation of dioxins and furans because of the presence of organics and chlorides and an ideal operating temperature. Parsons/Honeywell has been considering several options to limit the formation of these compounds in the CST. The recommendations will be incorporated into the final 250 hours of CST EDS I testing. This testing is expected to be conducted in July 2001. Perhaps the most promising approach would be to separately process DPE and wood, attempting to minimize the aromatic source from the chlorine. However, wood and DPE alone are each capable of producing dioxins and furans because they each contain organic compounds and chlorine. However, separation of the two materials is expected to reduce the quantity of dioxins and furans formed. Because there are no experimental data yet to support this design change, it has not been considered in the cost estimate. To isolate and remove dioxins and furans from gaseous emissions from the CST (and avoid contamination of the main HVAC filters), the Parsons/Honeywell design was adjusted to include a dedicated carbon filter for the CST effluent gas prior to its discharge to the main facility HVAC.

Particulate Formation. During the EDS I testing, fine particulate has been a cause of major problems with the operation of the CST. The fine particulate from the feed and carbon carrier attrition have caused foaming in the quench tower and plugging of the CatOx and flame arrestor. Particulate in the full-scale operation could be even greater due to higher wood throughput. The Parsons/Honeywell design currently has no means to remove these particulates from the gas

stream. Therefore, the design was adjusted to include dual cyclones in series followed by a barrier (candle) filter prior to the reheater. This equipment should be adequate to reduce particulate loading on the downstream equipment. Parsons/Honeywell is currently modifying the EDS I test unit to include a dual cyclone unit for the final 250 hours of testing. The particulate collected will have to be 5X treated in the BMPT because the residence time at temperature of the fines cannot be determined. Based on the EDS I testing, approximately one tray of dust would be generated daily from the CST. An analysis of the BMPT capacity showed that it could handle the additional throughput.

EDS I Test Result Incorporation. EDS I testing results (completed in December, 2000) are not incorporated into the submitted CST design submitted in the Parsons/Honeywell January 2001 Engineering Package. Among major concerns is the formation of dioxin and furan that was discussed above. In addition, the design does not use the EDS steam usage rate or include the choice of carrier material. The steam rate in EDS I was increased for two reasons. First, it was hoped that the increased velocity would carry more particulate out of the shell, thereby avoiding any insulating build-up and hot spots. Secondly, it was hoped that the increased steam rate would decrease the amount of dioxin and furan production. There are no data available to determine whether steam flow had any effect on dioxin or furan production. Because steam consumption affects the sizing of the quench tower and all downstream condensate handling systems, this issue needs to be resolved before detailed engineering design. Steam flow rates were not adjusted as a result of the design assessment.

During the EDS I testing, limestone was used as the initial carrier material however, the limestone caused serious plugging problems and was replaced with carbon. Alumina was considered to replace the limestone, but a short test with the material raised concerns that the CST could not handle the abrasive nature of the alumina. Therefore, Parsons/Honeywell decided on carbon as the carrier material. However, carbon attrition occurs with continued use (i.e., recycle) putting additional burden on the gas stream dust collection system downstream of the CST. EDS I testing showed a 5% loss of carbon fines per pass through the CST. The full-scale design in the Engineering Package uses alumina, but does not discuss how the CST would be modified to handle the material. Arthur D. Little has assumed continued use of carbon for the full-scale plant. To reduce carbon fines production, the Design Assessment has assumed that after CST solids discharge, 15% of the carbon that would normally be recycled is discarded to maintain a larger carbon average particle size. Carbon make-up rates of 15% will be used in operating cost estimates. Additionally, the carrier material supply and recycle has been modified and recosted to reflect the change from alumina to carbon.

Materials of Construction. Based on the Design Assessment, there is a concern that the current specified material for the CST, Hastelloy C276, (particularly the shell) may not be acceptable at the high-end of the temperature range required when using induction heating. The adequacy of the materials of construction specified for the full-scale design needs to be verified during the next phase of CST EDS I testing. During the initial EDS I testing, corrosion coupons were included in line. The results of this test indicated that Hastelloy C276 was an effective material of construction. During the next phase of testing, the gas side piping is being replaced from the CST unit to the quench tower with Hastelloy C276. The final 250 hours of testing will give some

indication whether the material is appropriate for the full-scale design. No change in the materials of construction will be made at this time for the purpose of cost estimation.

CatOx Performance. In EDS I testing, the CatOx units did not demonstrate high efficiency organics/hydrocarbons destruction. Inlet values of total hydrocarbons between 2000 and 4000 ppm were reduced to 500 to 1000 ppm. Carbon monoxide levels between 6000 and 7000 ppm were reduced to less than 50 ppm. Low molecular weight alkanes and chloromethane appear to comprise the majority of the hydrocarbons that passed through. However, ppb levels of benzene, acetone, toluene, and their mono-chlorinated analogs were also not being destroyed. Dioxins and furans were generated in the CatOx units. Not only were they being generated, but also higher proportions of the more heavily chlorinated compounds were found at the outlet than at the inlet. It is presumed that the existing dioxins and furans were being further chlorinated within the unit operation. Analysis to determine the fate of the mono-, di-, and tri- chlorinated compounds would be necessary to confirm this conclusion. The carbon beds appeared to capture most of the dioxins and furans that were being generated.

As mentioned above, the CatOx beds became plugged with particulate. The cyclones and candle filter should reduce particulate loading on the CatOx. However, subsequent to the January 2001 Engineering Package submittal, Parsons/Honeywell found that the CatOx beds were partially deactivated. For the cost estimate, dedicated carbon beds will be used for both dioxin and furan removal and for hydrocarbon removal. It may be necessary to add a parallel CatOx train to reactivate or replace the CatOx catalyst, but a parallel train has not been added at this time. Further EDS testing is required to evaluate whether the particulate removal system will eliminate the CatOx catalyst deactivation problems.

Defoaming Agent Impact on ICBs™. Defoaming agents will be used in the CST quench to prevent the production of foam seen during EDS I Testing. The condensate from the CST quench will contain the defoamers and they will be processed in the ICB™. The fate and effect of the defoamers used in the CST EDS I testing have not been tested or evaluated in the ICB™. It is recommended that Parsons use biodegradable defoamers (at least ones that are nontoxic to the microorganisms). Note that the quantity of defoamer used is very small.

Availability. Problems encountered during EDS I testing precluded achieving the 80% reliability/availability assumed for the full-scale design. EDS I testing demonstrated an availability of approximately 50%. Durations of outages were sometimes extensive due to modification of the equipment to improve reliability. Most of the problems related to feed system clogging, particulate production, and downstream particulate control issues. Even with modifications and improvements, CST system outage lengths can be long, if the CST has to cool for access to avoid igniting the carbon carrier. In addition, the CST, as designed, was not capable of decontaminating the dunnage materials as fast as they were generated within the facility. This caused the WHEAT schedule to extend for approximately 1 to 1.6 years beyond the end of agent operations.

Due to these two concerns, the WHEAT design was adjusted to increase the CST capacity to 125% of the current (submittal) capacity to handle additional amounts of wood that were not included in the WHEAT design basis (see 5.3.1.15) and a second train has been added to avoid

extending the schedule to finish processing the dunnage due to poor availability. The result is now two, 75% capacity trains.

5.3.1.8 Propellant Reconfiguration (Issue 10). Subsequent to submittal of the January 2001 Engineering Package, it became clear that the Depot would be allowed to reconfigure the remaining projectiles and mortars prior to demilitarization; therefore, PMACWA modified the design basis to eliminate the need for the Technology Providers to reconfigure the munitions. The PMACWA design basis still requires the Technology Providers to destroy the propellant, but the Depot will dispose of all the dunnage associated with the reconfiguration. The change in the design basis impacts numerous design issues and costs, including:

- Wood dunnage quantities to be treated
- Elimination of the need to treat fiber tubes
- PHA issues relating to the PRR
- Cost of the MDB
- Operating labor and material requirements

The impacts of this decision cascade through the PHA, design, cost and schedule assessments. Impacts and options are discussed relative to each issue.

5.3.1.9 Mustard Thaw (Issue 13). The Parsons/Honeywell design does not provide adequate provisions for thawing mustard during winter months. There is no analysis of the requirements or any discussion of the capability of the Munitions Storage Building (MSB) to accomplish this. The current single MSB provides only 24 hours holdup vs. 72 hours reported for adequate thaw, or only 33% of the storage capacity required. The issue was resolved during the Design Assessment by adjusting the design to include three MSBs to allow three days storage for thaw during winter months.

5.3.1.10 Agent Validation (Issue 14). Specific provisions for agent tracking were not included in the Parsons/Honeywell Engineering Package. This issue has been deferred to detailed engineering/design, which will incorporate all treaty considerations.

5.3.1.11 Dunnage Processing (Issue 15). In the January 2001 Engineering Package design basis amount of wood to be processed/destroyed by General Atomics (GATS) was approximately 50% greater than WHEAT. At the time of submittal, the wood dunnage quantity submitted by General Atomics was, with the exception of a minor error, correct. This amount included all of the pallets and all of the boxes (and fiber tubes) from unreconfigured munitions. Subsequent to submission, PMACWA determined that all Pueblo munitions would be reconfigured prior to the start of munitions destruction, and all reconfiguration wood and fiber dunnage would be disposed of by the Depot and not by the Chemical Stockpile Disposal Facility. PMACWA reconfirmed that all wood pallets would have to be processed and 5X treated. The quantity of wood dunnage has been recalculated to correct the Parsons/Honeywell error and incorporate updated pallet weights provided by PMACWA. The new quantity of wood dunnage has been incorporated into the CST sizing:

- 5.04 lb per 155mm round

- 2.42 lb per 105mm round
- 1.21 lb per 4.2-in. round

There is a five-fold difference between WHEAT and GATS design basis for the amount of DPE required to be processed. General Atomics assumed 0.7 lb per munition, Parsons assumed 0.15 lb per munition. Based on the experience at TOCDF, the Parsons number of 0.15 lb of DPE per munition is more correct.

The current Parsons design does not have any provision for dust control from the size preparation of the plastic and wood dunnage. No provision is made for dust control in the room in which the dunnage is prepared. No feed (to the CST) sizes are specified. The equipment listed is missing several components to realistically process, move, weigh and store the dunnage, and feed and remove material from the CST. Changing the carrier material from alumina to carbon (see 5.3.1.7) requires that the solids removal and recycle from the CST be redesigned.

Plant Section 120 and parts of Section 075 have been redesigned to realistically deal with the solids flow to and from the CST. The new design encloses the equipment for particulate control with air flow removal of dust. To avoid overloading the plant HVAC system, there is intermediate particulate removal prior to venting to the HVAC system. Explosion suppression is also provided. Screening is incorporated to assure maximum and minimum sizes (that will need to be specified) are compatible with the solids handling equipment and CST design.

5.3.1.12 Water Balance (Issue 16). There are significant inconsistencies and inadequacies in the water balance. The water quantities shown on the Water Balance PFD (AAC-00-F-140 & AAC-00-F-090) are from different operating conditions. Water generated or consumed in unit operations is not shown. However, based on the PFDs the water quantity in terms of usage and need is close.

During summer months, the process is expected to generate a maximum of 1,555 gal/day of excess water. The WHEAT design calls for this excess water to be stored in the “standard tank” for future makeup water. There is no indication of the number of days at this maximum generation and therefore, no way to assess the adequacy of the storage capacity required for the excess water. If the maximum excess quantity is produced for an extended period, there could be a significant impact on storage buffers. This issue is resolved by the resolution to Issue 8(a): replacement of the single 100% BRS train with two 100% equivalent trains. The two trains, together with the increased capacity and redundancy, provide sufficient capacity and reliability to evaporate excess water if necessary.

Finally, there is no water specification provided in the design basis for either incoming water to the facility or process water requirements. The lack of specifications makes estimating accurate capital and operating costs for water treatment and cooling difficult.

5.3.1.13 Effluents and Emissions (Issue 17). The Emissions and Effluents List provided by Parsons/Honeywell is basically a material balance-level document that lacks details in

characterizations of most streams. It is also incomplete in identifying all point source and potential fugitive emissions and effluents. Specific findings include:

- Incomplete characterizations – Many of the streams lack complete characterizations, particularly at the trace levels for contaminants of interest. Characterization data from the EDS I testing complemented process knowledge and engineering judgement need be factored into all streams shown in the Emissions and Effluent List.
- Omitted streams – Numerous streams are not included in the Effluents and Emissions List. These are primarily solid wastes and air emissions since the design is predicated upon zero wastewater discharge. Examples of air emissions that have not been included are: volatile organic compounds from fuel storage; evaporation and drift from cooling towers; and boiler flue gas. Many solid wastes are also not addressed, including both process-related wastes (e.g., spent hydraulic fluids and other wastes generated by maintenance activities) and non-process wastes (e.g., trash and sanitary wastes). One possible liquid waste that has been identified is boil-out from BRS evaporator maintenance. This water cannot be readily returned to the system because of the scale potential within the BRS itself. It is expected that it would have to be disposed offsite.
- New streams – In the course of the Design Assessment, several design modifications have been made to ensure design adequacy. One modification resulted in the addition of new point emissions to atmosphere from the BRS through a dedicated carbon filter system.

It is recognized that this is a preliminary listing, but it must be complete to the extent information is available. This is considered a significant deficiency in the January 2001 Parsons/Honeywell Engineering Package. A full list of effluents, emissions, and wastes must be prepared to support environmental permit and cost estimating.

5.3.1.14 Treatment of Non-process Wastes (Issue 18). Parsons/Honeywell and General Atomics make different assumptions regarding treatment of non-process wastes including waste oils and lubricants, hydraulic fluids, miscellaneous metal wastes, and miscellaneous refuse. General Atomics assumes treatment in the Supercritical Water Oxidation (SCWO) reactor and Parsons/Honeywell assumes disposition during Closure. No change in approach is needed but costs for disposal of these wastes was added to WHEAT cost estimate.

5.3.1.15 General Materials of Construction (Issue 19). The selection of materials of construction appears to be very preliminary and not well thought out in some areas. There are numerous inconsistencies and questionable selections. A detailed estimate of the impact of modifications to materials of construction was not prepared as part of the Design Assessment. Instead, a contingency (allowance) was added for materials upgrade during detailed engineering/design (see Section 8.0).

5.3.1.16 Instrumentation & Control Design (Issue 20). Instrumentation and control systems have yet to be thoroughly worked out, which is to be expected at this stage of a design. There are areas where control schemes appear overly complicated with several levels of cascaded controls. In other areas there appear to be additional controls required. In addition, a master control system is specified that may not yet be proven in commercial operations and there may be limited suppliers. It is difficult to assess the adequacy and appropriateness of control systems lacking a

detailed discussion and a thorough review of P&IDs, which are not yet complete. An overall contingency of 20% has been assigned to WBS 01.04.21 to include requirements for the control room itself, communications systems and process I&C systems.

5.3.1.17 Lab Provisions (Issue 21). The design and cost estimate includes retaining the freestanding Baseline Laboratory facility as well as space for a wet laboratory in the MDB. The Baseline Laboratory is dedicated to air sample analyses and, while the WHEAT technology does not involve incineration, a considerable amount of air sampling and analysis is still required to support both ambient and building air monitoring as well as stacks (e.g., MDB filter farm, BRS vent). The MDB laboratory is to provide the additional analytical capability required for liquid samples to support operations. These include agent, energetics and organics analyses. In addition, a laboratory capability is also required to support the biotreatment system, as is required for ABCDF. The latter could be a small, fairly “low tech” operation outside the MDB devoted to TOCs, organics, etc.

The costs for outfitting the MDB laboratory with the required equipment and a separate laboratory for the ICB™ have not been included in the capital costs. It has been assumed that the equipment cost would be a “trade-off” against the equipment in the freestanding Baseline laboratory that is assumed to not be needed.

The Baseline Laboratory was determined to be required for air samples and no costs could be diverted for outfitting the MDB and biotreatment laboratories. Capital cost allowances were derived from ABCDF estimates for comparable laboratories.

5.3.2 Technical Risk Assessment

The objective of the Technical Risk Assessment was to determine what subsystems within the WHEAT design had the potential to significantly affect the proposed cost or schedule. These subsystems could then be the focus, in the future, of additional design effort or potentially be replaced by another approach. The Technical Risk Assessment was performed in two steps. The first step was to determine an “inherent performance risk” based on the maturity level and complexity of each major subsystem. The second step was then to consider how each subsystem fit within the Parsons/Honeywell WHEAT design (including the Design Assessment adjustments) and to determine an “evaluated overall performance risk” for each subsystem within the WHEAT process.

The inherent performance risk is the technical risk associated with each subsystem independent of how that subsystem was used within the Parsons/Honeywell WHEAT design. The only design-specific information included in this assessment was the agent category where the equipment would be installed. To assign an inherent performance risk, a group of Arthur D. Little engineers was convened to discuss the maturity and complexity level of the major WHEAT subsystems. The group considered whether the subsystem had been used in a similar application within the Chemical Stockpile Disposal Project or industry and if so, at what scale. The group then considered whether the subsystems that had been operated on full-scale had been modified and the scale of testing for those subsystems that had not been operated at full-scale. Finally, the group considered the complexity of each of the subsystems and where the subsystems would be located within the facility. (The presence of agent can greatly increase the

complexity of maintaining even simple systems and make complex systems impractical.) Table 5-8 presents the assigned inherent performance risks for each major subsystem.

Once the inherent performance risks were assigned, the application of that subsystem within the WHEAT design was considered in order to assign an evaluated overall performance risk. The major input to this analysis was the Design Assessment presented above. Based on the analysis (see Table 5-9), two subsystem present a moderate level of risk: the RWM and the RMPT. Four subsystems present a moderate/low level of risk: the Burster Washout Machine, MDM, CST, and CST off-gas treatment. Due to these risks, a contingency was assigned to each of these subsystems in the Cost Assessment (see Section 8.0).

Additional discussion on any subsystem that was not considered to have both a low inherent performance risk and low evaluated overall performance risk is presented below.

Burster Washout Machine. The BWM received an inherent performance risk ranking of moderate. The BWM is based on the Parsons/Honeywell Demonstration I testing with Comp B burster washout. This testing was successful, but it was performed on Comp B and not tetryl or tetrytol. In addition, the machine that Parsons/Honeywell has designed has never been fabricated or tested.

Multipurpose Demilitarization Machine. The WHEAT MDM is a modified version of the Baseline MDM. It is complex piece of equipment that will be located in a Category A area and, as modified, it is untested. The resulting inherent performance risk ranking was moderate. Addition of a third unit improved the overall performance risk to moderate/low. Conceptual testing of the modifications will be conducting during EDS I testing of the Projectile Washout System.

Rotary Washout Machine. The RWM received an inherent performance risk ranking of high because it is an untested, custom-designed, complex piece of equipment that will be located in a Category A area. As with the MDM, addition of a third RWM improved the ranking, only to moderate in this case. Conceptual testing of the system will be conducted during EDS I testing of the Projectile Washout System.

Rotary Metal Parts Treater. The RMPT is a custom-designed, complex piece of equipment with a large rotating chamber that has the potential to be unreliable and difficult to maintain. It also relies on the as-yet unproven mechanism to maintain spacing between munitions and to volatilize and remove agent from horizontally arranged munitions and is located in a Category A area. Only one unit was included in the Parsons design. These factors contributed to the inherent performance risk ranking of high. With the addition of a second unit, the evaluated overall performance risk was improved but only to moderate because the potential for a performance shortfall remains.

Table 5-8: WHEAT Inherent Performance Risk

Equipment or Subsystem	Agent Category Designation	Equipment/Subsystem Development Maturity Level									Inherent Performance Risk ¹
		High			Medium			Low		Very Low	
		Full Scale Chem Demil Operations	Full Scale Chem Demil Operations Modified (Tested)	Commercial Directly Applicable (Tested)	Full Scale Chem Demil Operations Modified (Untested)	Commercial Directly Applicable (Untested)	Commercial Modified (Tested)	Commercial Modified (Untested)	Customized (Tested)	Customized (Untested)	
MSB	A/B	○									Low
UPA	C	●									Low
PRR	C				●						Low
WPMD	A/B	●									Low
ERD	A/B	●									Low
BWM	A/B				●						Moderate
WMDM	A				○						Moderate
RWM	A									○	High
RMPT	B								○		High
BMPT	B				●						Low
MPT OFFGAS	C			●							Low
Agent Hydrolysis	A			●							Low
Energetics Hydrolysis	C			●							Low
Dunnage Prep.	B/C			○							Low
CST	C								○		High
CST OFFGAS	C						○				High
ICB™	D			●							Low
ICB™ OFFGAS	D			●							Low
BRS	D			○							Moderate

● Proven in Full-Scale operations or testing, or otherwise justifies high performance credibility

○ Incomplete or partially successful testing or issues regarding performance

1. Inherent Performance Risk refers to the likelihood of significantly affecting proposed cost or schedule based upon Maturity Level, Application Level, and complexity of the equipment.

Source: Arthur D. Little, Inc.

Table 5-9: WHEAT Evaluated Overall Performance Risk

Equipment or Subsystem	EDS Design Submittal			Final Evaluation Configuration ²		Evaluated Overall Performance Risk ³
	Number of Units (Trains)	Capacity per Unit (Train) ¹	Comments	Number of Units (Trains)	Capacity per Unit (Train)	
MSB	1	33%	Lacks adequate thaw capability, residence time or heating	3	33%	Low
UPA	1	100%	---	1	100%	Low
PRR	1	100%	---	1	100%	Low
WPMD	2	50%	---	2	50%	Low
ERD	2	60%	---	2	60%	Low
BWM	2	60%	Testing scheduled to support design optimization	2	60%	Moderate/Low
WMDM	2	50%	Potential mechanical problems should be resolvable during Systemization	3	50%	Moderate/Low
RWM	2	50%	Thorough agent washout not critical per RMPT analysis	3	50%	Moderate
RMPT	1	120%	High potential for performance shortfall; redesign underway; BMPT an option	2	100%	Moderate
BMPT	1	120%	---	1	120%	Low
MPT OFFGAS	1	120%	---	1	120%	Low
Agent Hydrolysis	6	17%	Capacity represents potential pinch point per Throughput Analysis	6	22%	Low
Energetics Hydrolysis	3	33%	Capacity represents potential pinch point per Throughput Analysis	3	33%	Low
Dunnage Prep.	1	100%	Upgrades for fire protection and explosion avoidance required	1	100%	Low
CST	1	60%	High potential for lower availability than assumed; induction heating a risk	2	75%	Moderate/Low
CST OFFGAS	1	60%	Significant potential for lower availability/reliability than assumed	2	75%	Moderate/Low
ICB TM	4 x 4	30%	---	4 x 4	30%	Low
ICB TM OFFGAS	1	120%	---	1	120%	Low
BRS	1	100%	Significant potential for lower availability/reliability than assumed	2	75%	Low

1. Capacity is approximate based upon evaluated performance capability for the limiting campaign throughput

2. Bold face indicates an increase in number and/or capacity of equipment

3. Risk impact refers to likelihood of significantly affecting proposed cost or schedule based upon Inherent Performance Risk, capacities, redundancy and nature of issues.

Source: Arthur D. Little, Inc.

Continuous Steam Treater. The CST is another custom-designed unit. During EDS I testing, several problems were encountered including failure to meet full-scale reliability/availability levels, failure of the CST and reheater shells, and generation of particulates and dioxins and furans. In addition, the submitted design included only one unit. Design modifications to both the CST and CST Offgas Treatment system and the addition of a second unit have reduced the overall performance risk to low.

CST Offgas Treatment. The CST Offgas Treatment system is comprised of numerous basic components in series that results in a fairly complex system. The design adjustments prompted by problems with the generation of particulates and dioxins and furans added components to the system to minimize the problems observed during EDS I testing. While increasing the complexity, the design adjustments improved the performance of the system. In addition, a second CST Offgas Treatment train was added for the second CST. All of these changes combined to improve the risk ranking to low.

Brine Reduction System. The BRS received an inherent performance risk of moderate, due in most part to there being only one BRS train and the problems that have occurred with the Baseline BRA. With only one train there was a significant potential for lower availability than assumed in the Parsons/Honeywell design. The BRS is comprised of components that are commercially available and EDS I testing included operation of a laboratory system using actual ICB™ effluent as the BRS feed. The addition of a second BRS train resulted in an evaluated overall performance risk of low.

5.4 Design Assessment Conclusions

5.4.1 Viability of the WHEAT Process

After incorporation of the Design Assessment adjustments into the Parsons/Honeywell Design, the WHEAT process is considered to be viable in terms of operational efficacy and capability to consistently achieve the required levels of agent and energetics destruction as well as environmental performance. In addition, the Engineering Package with the Design Assessment adjustments, is adequate to support the +/- 20% cost estimate and to justify the proposed schedule.

The agent and energetic hydrolysis subsystems have been tested by the Army at a scale that clearly demonstrates their operational efficacy. In addition, both subsystems are considered to be noncomplex and to have a high availability due to the relative simplicity of their design as reflected in the following: limited rotating equipment, highly reliable equipment, significant sparing, limited sensitivity of the hydrolysis reaction to operating conditions, and large buffer storage capacity. The agent hydrolysis system has the additional advantage that a similar unit is the primary destruction process for the HD ton containers at ABCDF. ABCDF should be operational in time to incorporate lessons learned into the PUCDF agent hydrolysis subsystem. The secondary treatment process for the agent and energetic hydrolysates is also considered to be viable due to the significant amount of testing that the Army has conducted for both PMACWA and in support of ABCDF. Biological treatment is considered to be noncomplex because the hydrolysates have been cleared of agents and energetic prior to their treatment and the equipment is relatively simple to operate and control. Biological treatment offers the added advantages of

being relatively insensitive to changes in the operating conditions and being able to increase the capacity for short periods of time without a decrease in removal efficiencies.

Two treatment processes, the RMPT for munition bodies and the CST for secondary waste, are a source of technical risk. While the technical concepts for both the RMPT and CST have been demonstrated to be effective, neither subsystem has been utilized in an industrial operating environment and a prototype of the RMPT has not been fabricated. In addition both systems are considered to be complex due to the significant amount of rotating equipment, the need for sophisticated control systems, and the amount of equipment required downstream to control the emissions. The RMPT has the additional disadvantage of potentially having to handle agent, which complicates maintenance activities.

The CST has had a number of operational issues during the EDS I testing that could have an impact on its viability for implementation in a full-scale facility. The first is the generation of large quantities of fine particulate which has significantly reduced the reliability of the process and its downstream pollution abatement system. This problem is one found in numerous industrial processes and the solution should be based on EDS I and industrial operational data. The second problem, the generation of dioxins and furans is more difficult. These materials are present in both the condensate and gas streams. The dioxins and furans in the condensate will pass through the downstream processes and be disposed of with the salts from the brine, and the dioxins and furans present in the gas stream can be removed by carbon adsorption. Technically the dioxins and furans can be controlled and not released to the environment. However, the more important issue is the public concern that they are generated at all.

The technical risks associated with the RMPT and the CST were reduced by the adjustment of the Parsons/Honeywell design to include two 100% capacity RMPTs and two 75% capacity CSTs. The two additional units increase the capacities and the overall availability of the two subsystems. For the CST, the Design Assessment also adjusted the design to include a dual cyclone and barrier filter to control the particulate and to include a carbon filter on the gas stream from the CST prior to its discharge to the HVAC system.

Future design efforts should consider changing the RMPT to a batch system similar in nature to the BMPT or the Baseline Metal Parts Furnace (MPF). Both of these systems are less complex than the RMPT due to the manner in which munitions are fed to the unit. In addition, there is significant operational data on the MPF from both JACADS and TOCDF on which to base a design. Replacing the RMPTs with batch MPTs would allow the current small BMPT to be eliminated and its feed to be processed in the larger batch units. The larger batch units would also provide flexibility to the facility by allowing larger pieces of equipment to be decontaminated if necessary and/or treat other secondary wastes if the CST is not meeting operational requirements. Consideration should also be given to replacing the induction heaters proposed for the CST, RMPT, and BMPT with resistance heating elements. Resistance heating is intrinsically safer and less complicated than the induction heaters.

The area of highest technical risk with the WHEAT design is in the reverse assembly process, which is based on the Baseline process. During the three mustard campaigns at JACADS, the reverse assembly process was the bottleneck for the entire facility. Specifically, the MDMs

operated significantly below expectation due to problems with draining the agent, the size of the agent heels remaining, the difficulty pulling the burster well, and the champagning of the mustard when the burster well was pulled. Parsons/Honeywell has modified the MDM and added the RWM to resolve these issues; however, testing of the proposed modifications is currently undergoing EDS I testing and results are not available for this assessment. Even if the ongoing tests are successful, the Parsons/Honeywell design still has a significant technical risk in this area because of the complexity of the equipment, the presence of agent, and the sensitivity of the equipment to variations in the munitions.

To reduce the technical risk in this area, the Design Assessment increased the number of MDMs/RWMs from two to three and added buffer capacity between the PMD and the MDM. Both of these adjustments moderate the technical risk and the ongoing EDS I testing may reduce it further. However, the area will still represent the largest risk within the design for cost or schedule “creep.”

5.4.2 Comparison of WHEAT to Baseline from a Design Perspective

From a high level view, the WHEAT and Baseline designs have very similar technical risks and the critical path through both facilities is through very similar processes. The largest technical risk for both WHEAT and Baseline (see Appendix A) is the reverse assembly process. WHEAT has proposed modifications to increase the operability and reliability of this area, but it is still fundamentally the same approach that has caused problems in the past and may be a problem in the future due to its sensitivity to differences in the munitions. General Atomics, on the other hand, has made a paradigm shift by replacing the MDM with cryofracture which could significantly reduce the technical risk for the PUCDF operations. The Baseline design for PUCDF still uses the reverse assembly process as operated at JACADS, which is not a viable solution. For the Design Assessment, the assumption was made that Baseline would change the design of the reverse assembly area to correct for the operating problems, but to date that design effort has not been started.

The critical path for both WHEAT and Baseline (see Appendix A) goes through the reverse assembly process to the munition bodies treatment process, the RMPT for WHEAT and the MPF for Baseline. The reliability, availability, and maintainability for these subsystems is almost identical (after assuming Baseline redesign of the MDMs). Therefore, the operating schedules for both technologies are essentially the same.

The Baseline technology does have the advantage of more operational data; however, the advantage is not as great as one might envision due to the need to significantly redesign the MDM to handle the mustard munition accessing problems at JACADS and the MPF to handle significantly higher quantities of agent. The liquid incinerator (LIC) and the deactivation furnace (DFS) could be based on the JACADS operations with little change; however, WHEAT will have the advantage of the agent hydrolysis operations and biological treatment at ABCDF and the extensive energetic water washout data for conventional munitions. Therefore, the maturity of both technologies is considered to be similar.

The area of major difference between WHEAT and Baseline is the method chosen for the destruction of the agent and energetics. WHEAT uses a hot water hydrolysis process for the

agent and a caustic hydrolysis process for the energetics with biological treatment of the hydrolysates. Baseline uses incineration for both agents and energetics.

In summary Baseline and WHEAT are very similar in the areas of technical risk and maturity. The significant difference is the choice of the primary destruction technology (hydrolysis vs. incineration) for the agents and energetics.